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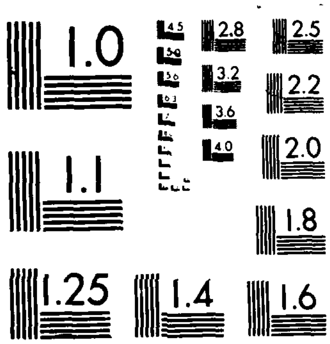

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Biological Sciences

Selected presentations by researchers from the UK, West Germany, the Netherlands, and the US on neuronal development in nonmammalian organisms and in mammalian systems are summarized. The presentations dealt primarily with morphological studies of early neural development in a wide range of species.

This meeting, held in Prague, Czechoslovakia, gave clear evidence of the greatly increased use of molecular biological techniques to investigate problems in neurobiology which can not be approached by conventional biochemical methods. The article reports on the impact of molecular genetics on neurochemistry, immunological approaches to study synapses and development of the nervous system, and neurotransmitters and peptides in stress.

Chemistry

High-temperature corrosion of materials and coatings for energy systems and turboengines were the concerns of this symposium, held in Marseilles, France, in July 1986. Topics covered in this article include gaseous oxidations, growth and adherence of protective oxidescales, corrosion by molten salts, ceramics corrosion performance, and coating technology.

Computer Sciences

Brief descriptions are given of EUREKA projects approved in November 1985, and comments are offered on the success of EUREKA to date in progress toward fulfillment of its initial promise.

Mechanics

Some of the research areas of the Aeronautics and Energetics Departments of ONERA, the French National Institute for Aerospace Research and Studies, are discussed. With their young and productive staffs and extensive experimental and computational facilities, these departments are expected to continue in their vital role in European aerospace research.

The Vortex Flow Symposium, held in Stockholm, Sweden, in October 1986 marked the end of a collaborative project known as the "International Vortex Flow Experiment on Euler Code Validation," which involved the Netherlands, Sweden, West Germany, and the US. This article summarizes the results of the 4-year project as presented by the participants.

Physics

An overview of the STM '86 conference is given along with a sumary of presentations covering new STM instruments, automation, and methodology and STM applications to metal surfaces and metal interfaces, electrochemistry (fluid/solid interfaces), graphite, organic and biological molecules, lithography and micromachining, and semiconductors.

This article discusses highlights of current research in scanning tunneling microscopy in certain laboratories located in Switzerland, Spain, The Netherlands, West Germany, and the UK.

An in-depth review of the 18th Conference of the European Group for Atomic Spectroscopy (EGAS) is presented. The breadth of topics was astounding. The article also has a section on the Darmstadt heavy ion accelerator facility, focusing on development plans and future experiments.

The 3rd International Conference on Advanced Infrared Detectors and Systems, held in London in June 1986, was a profoundly successful gathering of European experts, mainly British, German, and French. This article reviews selected presentations in the areas of IR detectors and sensors (silicon technology as well as other materials); radiation effects (meaning emissivity, propagation, and IR signature studies); and systems for surveillance, multichannel devices, and automatic tracking.

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News and Notes

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Biological Sciences

NEUROBIOLOGY WORKSHOP: "THE MAKING OF THE NERVOUS SYSTEM," WYE COLLEGE, UNIVERSITY OF LONDON, KENT, JULY 1986

by Claire E. Zomzely-Neurath. Dr. Zomzely-Neurath is the Liaison Scientist for Biochemistry, Neurosciences, and Molecular Biology in Europe and the Middle East for the Office of Naval Research's London Branch Office. She is on leave until July 1987 from her position as Director of Research, the Queen's Medical Center, Honolulu, Hawaii, and Professor of Biochemistry, University of Hawaii School of Medicine.

Introduction

This neurobiology workshop, dealing with the development of the nervous system, was attended by 130 participants from nine European countries, Israel, and the US, with the largest representation from the UK followed by the US and The Netherlands. In addition to the presentations by invited speakers, there were 50 poster sessions.

Developmental neurobiologists study many different animal species in an attempt to extract general principles of neural organization during development. This was very evident in the context of the workshop, in which the research presented ranged from studies of the neuronal development of the nematode (round worm), leech, goldfish, and chick to the mouse and rat. The emphasis of the presentations was on morphological studies, and therefore essentially descriptive in nature. However, it is important to realize that this type of study provides the basis for neurochemists to investigate specific molecules such as growth factors, cell surface molecules, and extracellular components that may be involved in neuronal organization and guidance of neuronal growth to their respective targets. Morphological studies have become quite sophisticated with the use of antibodies made to cell components, immunohistochemical techniques, and tissue culture methods.

In the following section, a summary of selected topics from the intensive workshop on nervous system development is presented.

Neuronal Development: Non-Mammalian Organisms

Neuronal Development in the Nematode. A detailed and interesting series of studies on neuronal development using a very simple model, the nematode (*Caenorhabditis elegans*) was presented by R. Durbin (MRC Laboratory of Molecular Biology, Cambridge University, UK). The advantages of using the nematode (round worm) are (1) it has only 302 nerve cells; (2) it has a short life cycle--3 days from egg to adult form; (3) many mutants are available so one can readily study the effects of genetics as well as environment; (4) all cells are identifiable at each stage of development. Durbin's report dealt primarily with the central nervous system of the nematode. Of three possible cell lineage patterns (clonal, stem cell, and repeated sublineage), he found that the latter pattern appeared to be dominant and was shown most clearly in postembryonic ventral cord and neuroblasts. Using mutants and isolated genes, Durbin observed that cell death of some embryonic nerve cells occurring shortly after birth was a type of "suicide" death (programed cell death) for the apparent purpose of making variations in cell lineage. In addition, using a focused laser beam to kill particular, defined cells, Durbin found that factors from the ventral cord determined what happened during development to various types of neuronal cells. Also, he observed that there was a replacement of a particular cell type with another, rather than regeneration of the ablated cell type. If he ablated a parent neuron, there was disorganization of development and two types of cells (A and G) seemed to be involved in organization.

Neuronal Development of the Leech. Neuronal development in organisms with a much more complex nervous system than the nematode, i.e., the leech (blood sucker), was studied by S. Blackshaw (Institute of Physiology, University of Glasgow, UK). This insect contains 15,000 cells in the central nervous system (CNS). Blackshaw observed that in the leech, as was found in the nematode, a selected loss of neurons occurred during development (30 days from egg to adult). He used microinjection of horseradish peroxidase (HRP) into early cells of the leech embryo as well as fluorescent tracers to follow cell lineage and monoclonal antibodies (Mabs) to leech muscle. Blackshaw found that the neurons appear to have identities prior to axon development and to be able to find their way to their final target.

Neuronal Development and Connectivity in *Xenopus laevis*. An excellent talk on neuronal development and connectivity in *Xenopus laevis*, a model with a much more complex nervous system than the leech, was presented by S. Fraser (Department of Physiology and Biophysics, University of California, Irvine, California). He used highly sensitive fluorescent dextrans (i.e., lysinated rhodamine dextran [LRD] and lysinated fluorescine dextran [LFD]) to look at cell lineage in early embryos and neural projections during development. At the 16-cell stage, Fraser injected LRD into one cell of the *Xenopus* embryo and LFD into another cell to follow interactions during neuronal development. He found that at Stage 14, neural folds were forming and closing and that clones of cells were somewhat coherent. By Stage 39, there was some coherence but much more mixing of cells. No recycling was seen with this double-label method; i.e., red cells (LRD) were never yellow cells (LFD).

Neuronal Development of the Retinotectal system of *Xenopus laevis*. Fraser is also studying neuronal development by cultivating cells at different stages of development and, using the labeled dextrans, can perturb the cells to study effects on cell lineage. In addition, he has developed a method by which he can image *Xenopus laevis* directly, after the yolk is used up, by means of epifluorescent microscopy. He has been studying, in particular, the retino-tectal system. By the use of very small grafts (eyebuds) and the double-label method, he was able to study the topography of axial projections in the living *Xenopus*. Fraser found that the establishment of topography appears to be a slow process and the fibers appear scrambled when they arrive at their target, the tectum. However, 2 days later, the fibers appear to be very organized.

Studies of Neuronal Development in Amphibian Embryos Using Lithium. Some intriguing studies using lithium, a potent teratogenic agent, to investigate the effects of morphogenetic alterations during neuronal development of amphibian embryos was reported by A. Warner (Department of Anatomy, University College, London, UK). It was necessary to treat the embryos with high amounts of lithium (100 mM) since she found that the embryos were quite impermeable to lithium (Li) with an internal concentration of only 2.5 mM Li. Warner's results showed that Li inhibited morphogenesis and also affected patterning. However, using Mabs to neurofilament proteins as a marker of neuronal differentiation, she found that differentiation was not affected by Li. In order to obtain quantitative information, Warner used tissue culture methods. With Li, she observed a doubling in the number of differentiated neurons in spite of marked effects of Li on patterning and morphogenesis. Thus, with the use of Li, Warner was able to separate differentiation from morphogenesis and pattern; a procedure which is valuable for studying differentiation.

In another study of anatomical patterning, Warner used antibodies (Ab) to gap junction protein. She found that this Ab interfered with patterning and that three or more signals might be involved in each stage of patterning.

Neuromuscular Junction Function in *Xenopus* embryos. Synaptogenesis *in vivo* was studied by F. Allen (Department of Anatomy, University College, London) using dye transfer between muscle and nerve cells to test for direct cell-to-cell communication during early events in neuromuscular junction formation. Myotomes and neural tubes were isolated from *Xenopus* embryo at Stages 18 to 20, dissociated, and cocultured. It was found that muscle and nerve were transiently dye-coupled through gap junctions during initial contact *in vitro*. This gap junctional communication could play an important role in the formation of neuromuscular junctions.

Nerve Regeneration in Optic Nerve and Tracts of *Xenopus laevis*. A detailed morphological study on optic nerve and tracts of *Xenopus laevis* by following regeneration of fibers after cutting or crushing of the optic nerve was carried out by J.S.H. Taylor and R.M. Gaze (Department of Zoology, University of Edinburgh, UK). They found that if the optic nerve is cut or crushed at any position extracranially no large-scale ipsilateral regeneration of fibers to the target (tectum) is seen, as is the case if the fibers of the optic chiasma itself (where crossover takes place) are damaged. Furthermore, if axons regenerating from one eye are confronted in the chiasma by degenerating or regenerating axons from other eyes, they do not alter their generally (normal) contralateral growth.

Visualtectal Mapping in *Xenopus laevis*. An interesting approach to understand the positional cues which guide optic fibers to their correct place in the tectum of *Xenopus* was used by N.A. O'Rourke and S.E. Fraser (Department of Developmental Cell Biology and Department of Physiology and Biophysics, University of California, Irvine). In this study, the temporal half of the right eyebud was replaced with the temporal half of a left eyebud, creating a nasal right-temporal left (NrTi) eye with the grafted temporal half inverted along its dorsoventral axis. Visualtectal mapping of NrTi eyes in Stage 56 larvae up to adults revealed either normal or double-nasal maps, both of which had normal dorsoventral polarity. O'Rourke and Fraser interpreted this as a respecification of the dorsoventral axis in the grafted temporal half of the NrTi eye. They used a vital-dye fiber-tracing technique (lysinated rhodamine dextran and lysinated fluorescine dextran) to mark the retinal ganglion cells and their axons during initial map formation. It was observed that the labelled cells remained in the positions in which they were grafted and contributed to the growth of the retina. The fibers from these cells projected to the tectum according to their original position in the donor eyebud (mosaic pattern) rather than their final position in the host (regulated pattern). Thus, it appeared that newly added cells at the margin of the eye must make up the regulated projection pattern. To address this, anterograde horseradish peroxidase (HRP) labeling of groups of fibers from newly added cells in the temporal half of the NrTi eyes was performed. In the early 50's Stages, some of the peripheral cells were found to project in a mosaic pattern while other cells were found to project in a regulated pattern. The regulated pattern emerges in the projections of cells at the periphery of the compound eye after an initial period when the grafted cells at the center of the retina project only in a mosaic pattern.

The development of brain stem neurons with anatomical and neurophysiological techniques in relation to locomotion in larvae of *Xenopus laevis* at Stages 25 to 40 was studied by P. van Mier, H.J. Ten Donkelaar (Department of Anatomy and Embryology, University of Nijmegen, The Netherlands) and A. Roberts (Department of Zoology, University of Bristol, UK). Experiments in which HRP was applied to the caudal brainstem revealed that at Stages 25, 32, and 40, ingrowing supraspinal axons from many brainstem neurons had reached the level of the first, seventh, and 24th myotome. At these stages, locomotor activity could be recorded extracellularly from, respectively, the first, third, and 30th intermyotomal clefts. The recordings indicated that reticular neurons, at least those in the caudal brainstem, take part in locomotion and that these neurons participate quite early in development.

Development of Cerebellar Connections in *Xenopus laevis*. A detailed morphological study on the development of cerebellar connections in *Xenopus laevis* using HRP as a retro- and anterograde tracer was presented by J.A. M. van der Linden and H.T. Ten Donkelaar (Department of Anatomy and Embryology, University of Nijmegen). They found that by Stage 48, most of the cerebellar connections observed in adult *Xenopus* were already present. Furthermore, with the indirect immunofluorescence technique using an Ab to serotonin, labelled fibers were found in the molecular layer at Stage 54 and at Stage 48, distinct cerebellovestibular projections were already present.

Nerve Regeneration of Optic Axons in Goldfish. The tectal pathways of goldfish optic axons during optic nerve regeneration following removal of either the nasal or temporal half of the retina was investigated by C. Stuermer (Max-Planck Institute for Developmental Biology, Tübingen, West Germany). The pathways were examined in whole, mounted tecta which were processed by the diaminobenzidine technique to reveal anterogradely transported HRP applied to the nerve or the eye. Their results showed that nasal fibers followed very similar pathways to those of whole retina regenerates. However, the temporal fiber pathways differed significantly from whole retina regenerates by forming many fascicles that crossed the tectal midline and by having many more fasciles in deep tectal layers.

Studies on regeneration of axons of the optic tract in goldfish was reported by D.L. Becker (Department of Anatomy and Embryology, University College, London). In the goldfish, the optic tract splits into two brachia just before it reaches the optic tectum. The division is normally very specific but is less so when the optic nerve has been cut and regenerated, even though an orderly retinotectal projection is re-formed. Becker investigated the selectivity of regenerating optic axons for the correct brachia using HRP for axon labeling. He observed a high error rate early in regeneration, suggesting that axons enter the brachia randomly. As guidance is necessary to fix the polarity of the regenerated retinotectal projection, it would appear to be given after bifurcation. The subsequent increase in specificity observed by Becker implies a loss of axons from the incorrect brachia as regeneration proceeds.

Nerve Regeneration in Goldfish Spinal Cord Fibers. The regenerative capacities of fiber groups in the goldfish spinal cord were studied by S.M. Bunt, K.A. Black, and P.J. Kirkpatrick (Department of Anatomy, University of Dundee, UK). They found that even within a species such as goldfish, where spinal cord axons are thought to regenerate fully, some fiber types were incapable of regeneration. By backfilling cells in the brainstem from spinal cord application of HRP, Bunt et al. were able to identify the cells sending fibers down the spinal cord of normal goldfish. Comparison of their results from regeneration experiments with normal goldfish, enabled Bunt et al. to identify the cells which were unable to regenerate.

Neural Crest Migration in Chick Embryos. Some of her research on the guidance of neural crest migration during ontogeny of the peripheral nervous system in chick embryos with the use of antibodies as markers was presented by M. Bonner-Fraser (Department of Physiology and Biophysics, University of California, Irvine). These are powerful tools for following neuronal development. One antibody, HNKI, stains dorsal root ganglion (DRG) cells and is selective for neural crest cells when they start to migrate from the posterior end of the neural tube. Bonner-Fraser showed with some elegant slides that the crest cells start to migrate just after the neural tube closes and that these cells migrate through the schlerotome, entering through the anterior part at the change from epithelial cells to form schlerotome.

Bonner-Fraser also used tissue cultures (neural crest cells grown on fibronectin and laminin substrates) to study the role of the extracellular matrix molecules in guiding migration. She obtained an antibody (JG22) which affects the adhesion of neural crest cells to fibronectin and laminin. Her results showed that the antibody appeared to affect cranial neural crest cell migration but not neural crest cells of the trunk region.

Adrenergic and Cholinergic Neurons in Chick Embryo. Adrenergic expression in transplanted cholinergic neurons was investigated in a very interesting study, by J. Coulombe and Bonner-Fraser (University of California, Irvine). It is known that under appropriate conditions, sympathetic adrenergic neurons can acquire cholinergic traits. The present study was designed to ascertain if the reciprocal transition can occur; i.e., that cholingeric neurons can acquire adrenergic properties. Cholinergic ciliary neurons from 6.5-day quail embryos were selectively labelled using fluorescent latex microspheres retrogradely transported from the iris region. A dissociated cell suspension containing these neurons was then microinjected into 2.5-day chick embryo. Their results showed that some, but not all, cholinergic cilliary neurons are able to synthesize or take up catecholamines when transplanted into sites where neural crest cells differentiate to form adrenergic cells.

Growth Factors of Developing Sensory Neurons in the Chick. In a biochemical study, growth factor requirements of developing sensory neurons in the chick was investigated by R. Lindsay (Sandoz Institute for Medical Research, London). Lindsay used various systems to study the effect of trophic factors in developing neurons: explants of single ganglion; mixed ganglion explants; and dissociated, enriched neurons. He used nodose ganglia (NG) from cranial nerve to look for growth factor activity other than that of the well-known nerve growth factor (NGF). NG was used since it does not respond to NGF. Lindsay found evidence for a new growth factor partially purified from chick liver extract which had a pronounced effect on NG neuronal outgrowth and survival. A brain extract which also exhibited a trophic effect could be replaced by brain-derived neurotrophic factor (BDNF). BDNF was also found to affect retinal ganglion cell survival, indicating that this factor also has an effect on central as well as peripheral neurons.

Neuronal Development: Mammalian Systems

New Growth Factor Found in Mouse Embryo. Studies on a new factor produced by the target field of trigeminal ganglion (TG) in the mouse embryo was presented by A.G. Lumsden (Department of Anatomy, Guys's Hospital Medical School, London). He called his growth factor MF (Max Factor). Lumsden found that response to MF was restricted to TG neurons and that the response was elicited only during the period of outgrowth of the TG neurons. MF was produced by the epithelial target and not by the mesenchymal pathway and was immunochemically distinct from NGF.

NGF mRNA in Mouse Embryo. A.M. Davies and H. Thoenen (Max-Planck Institute for Psychiatry, Martinsried, West Germany), who are well-known for their extensive and elegant studies of NGF, presented some of their recent work on the site and timing of NGF messenger RNA (mRNA). NGF and its mRNA were measured in the embryonic mouse trigeminal ganglion and in part of its cutaneous target field (the maxillary process) at closely staged intervals throughout development using a two-site enzyme immunoassay and a complimentary RNA (cRNA) probe. They observed that NGF does not attract nerve fibers to their target during development. The levels of NGF and its mRNA increased in parallel during the early stages of innervation, suggesting that NGF synthesis is under transcriptional control. Also, NGF, but not its messenger, was detected in the ganglion 24 hours after innervation begins, demonstrating axonal transport of endogenous NGF and accounting, in part, for the fall in the target field content of NGF observed at later stages of development. There was a substantial increase in the target field content of NGF mRNA at the time of differentiation of whisker follicles, the most densely innervated structures in the skin. NGF mRNA was present in both the epithelium and mesenchyme of the target field with a several-fold higher concentration in epithelial cells.

Development of Somatostatin Neuron in Rat Visual Cortex. A detailed electron microscopic study on the development of somatostatin-immunoreactive neurons (SIF) in the visual cortex of the rat using the peroxide-antiperoxidase labeling technique was carried out by L.A. Eadie and J.G. Parnavelas (Department of Anatomy, University College, London). They found that, at birth, some SIF-positive neurons already express some of the characteristic features seen in the adult. The percentage of SIF-positive neurons that have obtained adult features increases throughout the first two postnatal weeks with most expressing these features by postnatal day 14. SIF-positive neurons were indistinguishable from those of the adult by the third postnatal week.

Neuropeptide Y in the Developing Rat Cortex. An interesting study to examine neuropeptide Y (NPY) in the developing rat cortex was reported by P.L. Woodhams (MRC Developmental Neurobiology Unit, London). Woodhams combined NPY immunocytochemistry with retrograde transport of wheat germ agglutinin-HRP from small unilateral injection sites in the contralateral cortex. The results showed that the majority of layer V neurons were NPY-positive at birth and disappeared during the first postnatal week. These neurons appeared to have a homotropic projection to the contralateral cortex. Since mature layer V pyrimidal cells have never been shown to contain NPY, Woodhams proposed that this transient NPY projection is important in a developmental context, perhaps in regulating morphogenesis or synaptogenesis of the target area.

Development of Dopamine and Cyclic AMP-regulated Phosphoprotein in the Rat CNS. An elegant study on the ontogeny of dopamine and cyclic adenosine-3, 5'-monophosphate regulated phosphoprotein of 32 kilodaltons (DARPP-32) in the rat CNS using immunocytochemistry was carried out by G.A. Foster (Department of Physiology, University College, Cardiff, UK). The appearance of tyrosine hydroxylase (TH) was analyzed simultaneously. Of particular interest was the observation that the arrival, within a given brain region of the presumed dopaminergic, TH-containing innervation, part of whose postsynaptic function is putatively mediated by DARPP-32, was preceded by at least 2 days by the appearance of DARPP-32-containing cells. Moreover, the subsequent reorganization of the DARPA-32-positive somata within the caudate nucleus into clumps, predated the aggregation of the TH-fibers into the same microzone. Thus, the appearance of DARPP-32 is not dependent on the presence of a dopaminergic innervation. Indeed, its existence in dopaminergic neurons prior to the arrival of their input raises the possibility that one of the effects mediated by DARPP-32 is to induce or stabilize the synaptic contacts formed by dopaminergic terminals.

Maturation of Motor and Sensory Areas of Rat and Human Spinal Cord. A detailed study on the neurochemical maturation of motor and sensory areas of the spinal cord of rat and man assessed by immunoreactivity for neurofilament protein (NF), substance P (SP), somatostatin (SOM), calcitonin gene-related peptide (CARP) and galanin (GAL) was reported by E. Marti, S.J. Gibson, P. Facer, H. Koltzenberg, and J.M. Polak (Department of Histochemistry, Royal Postgraduate Medical School, Hammersmith Hospital, London, UK). The developmental pattern of the peptides (SP, LOM, CGRP, and GAL) were analyzed in order to establish a possible differential expression between motor and sensory areas of the spinal cord. The presence of NF was used to assess the extent of neuronal maturation. The results showed that the motor system matured anatomically and neurochemically before the sensory system. This apparent late development of peptides in the dorsal horn may be related to the delayed onset of normal C fiber function.

Changes in Cytoskeletal Elements During Development of the Rat Visual Cortex. Changes in cytoskeletal elements during postnatal development of the rat visual cortex and its possible relation to the critical period of plasticity were studied by S.N. Norma and J. Cronly-Dillon (Department of Ophthalmic Optics, University of Manchester, UK). The concentrations and rate of synthesis of cytoskeletal elements (microtubules, microfilaments, and neurofilaments) were measured. Their results showed that the developmental profile for tubulin and F-actin (components of microtubules) correlated with eye-opening and the duration of a sensitive plastic phase in visual cortex development. Neurofilaments were found to be associated with late maturation and the termination of the plastic phase.

Developmental Changes in GABA Release in the Rat. A study of developmental changes in calcium dependency of the putative neurotransmitter, γ-aminobutyric acid (GABA), released from isolated growth cones of the rat was reported by J. Taylor and P.R. Gordon-Weeks (Department of Anatomy and Human Biology, King's College, London, UK). These investigators observed age-related increases in the proportion of K^+ stimulated $[^3H]$-GABA release that was dependent on extracellular Ca^{2+}. Thus, there appears to be a developmental change in Ca^{2+} dependency of GABA release from growth cones such that in the older rat pups the release more closely resembles that of adult synapses.

Conclusion

The presentations at this workshop dealt primarily with morphological studies of early (embryonic) neuronal development in a wide range of species from the simple nematode to the complex nervous system of mammals such as rat and mouse. Immunohistochemical techniques and markers such as horseradish peroxidase have facilitated developmental studies and made possible ways to readily follow progression of development. Neurotrophic and hormonal factors playing roles in neuronal development were also addressed by some of the speakers. The quality of the research presented was excellent and provides a basis for future collaborative biochemical and molecular biological studies.

8/22/86

NEUROBIOLOGY: SIXTH MEETING OF THE EUROPEAN SOCIETY FOR NEUROCHEMISTRY

by Claire E. Zomzely-Neurath.

The sixth meeting of the European Society for Neurochemistry (ESN) was held in Prague, Czechoslovakia, from 1 through 6 September 1986. There were 850 participants from 32 countries, with the largest representation from Western and European countries. The distribution was unusual in that scientists from Eastern European countries constituted 43 percent of the total member of attendees, the greatest number from the USSR and Czechoslovakia. This was due to the fact that the conference was held in an Eastern European country.

The format of all ESN meetings, including the Prague conference, consists of a plenary lecture dedicated to the presentation of the art in one area of neurobiology and of symposia, of which at least one is focused on a subject of major interest to clinicians. In addition, there are workshops and roundtables on specialized topics as well as poster presentations. At each meeting, two or three young scientists chosen before the meeting present their research as the ESN Honorary Lecturers.

The wide range of topics covered at the meeting included molecular and immunological approaches to studies of the nervous system; the role of gangliosides, neuropeptides, and neurotransmitters and their receptors; neurogenesis; and neuropathology as well as other research areas.

Because of the large number of scientific presentations as well as concurrent sessions, this report encompasses selected topics dealing with areas of recently increasing emphasis in neurobiology which are being actively pursued by European neuroscientists. A more detailed report is presented in ONRL report C-8-86.

The publishing houses of John Wiley and Sons (Chicester, UK) and Academic (Prague) will publish two volumes with articles based on the lectures given in the symposia, workshops, and roundtables. The titles of these volumes will be "Metabolism and Development of the Nervous System" and "Synaptic Transmitters and Receptors," thus reflecting the themes of the ESN meeting in Prague. The anticipated publication date is within 6 to 12 months.

The Impact of Molecular Genetics on Neurochemistry

This research area was emphasized in a large number of the presentations at the Prague conference in marked contrast to the ESN meeting in Budapest, Hungary, 1984 (ONRL report C-7-84), at which minimal attention was given to the impact of molecular genetics.

In his excellent plenary lecture E.A. Barnard (MRC Molecular Neurobiology Unit, MRC Center, University of Cambridge, UK) dealt with the relatively new and exciting area of research in neurobiology, namely, the cloning of genes for receptors for neurotransmitters and neurohormones using the immensely powerful methods of modern molecular genetics. He pointed out that cloning of the DNA's which encode the receptor subunits can provide the entire amino acid sequence, an attainment generally beyond the range of conventional approaches to protein sequencing. These clones can also yield radiolabeled hybridization probes for analyzing the development and regulation of receptors at the messenger RNA (mRNA) levels as well as for tracing the chromosomal and cellular locations of their gene expression. Barnard also emphasized the use of the *Xenopus* oocyte system for cellular translation of receptor mRNA's as this system offers great advantages for such studies and can provide new information in its own right on receptors. He presented data from his own research and collaborating laboratories on the muscle and brain nicotinic acetylcholine receptors (AChR's), the brain and amino-butyric acid (GABA) receptor, and a brain opiate receptor. Barnard also pointed out that the combined results of gene cloning, hybridization tracing, and experimental gene modification are providing a whole new dimension of insights into the nature and function of neuronal receptor systems.

In the symposium session, some of their excellent work on the analysis of clone DNA encoding nicotinic acetylcholine receptor subunits from the chicken central nervous system (CNS) was presented by M.G. Darlison, J. B. Cockcraft, A.A. Hils, M.D. Squire, S.T. Moss, and E.A. Barnard (MRC Molecular Neurobiology Unit, MRC Center). These investigators, using recombinant DNA (rDNA) technology, examined the existence and structure of these receptors in the brain. DNA fragments encoding subunits of the chick peripheral nicotinic AChR were used to probe chick optic lobe complementary DNA (cDNA) libraries for homologous brain sequences. They found that CNS neural nucleotide sequences exhibited strong homology with peripheral AChR subunit sequences but that significant differences were observed, particularly in the region between the transmembrane segments M3 and MA. They also isolated a chick genomic clone by cross-hybridization at high stringency using an optic lobe cDNA clone. An analysis of the nucleotide and primary sequences of these clones was presented.

Some of their continuing first-class work on the regulation of the tubulin multigene family was presented by I. Ginzburg and U.Z. Littauer (Department of Neurobiology, the Weizmann Institute of Sciences, Rehovat, Israel). Tubulins are the main components of microtubulins, which are particularly important in the brain where they are involved in cell differentiation, migration, and synaptic transmission. In mammalian DNA, hybridization experiments with labeled cDNA probes have revealed the presence of α- and β-tubulin gene families. Ginzburg and Littauer constructed specific cDNA probes to study the expression of an individual member of the tubulin gene family. Two α-cDNA clones were isolated and their nucleotide sequence was determined. The two clones shared high homology within the coding region of the gene but were highly divergent in the noncoding region. The nucleotide sequence of the rat brain β-tubulin showed a high homology when compared to chicken and human β-tubulin sequences but no homology was observed at the noncoding region. Comparison of the derived amino acid sequences from different species demonstrated that the amino acid changes are not randomly distributed but rather there are several conserved and two highly variable regions common to β-tubulin polypeptides from various sources. Ginzburg and Littauer found that three β-tubulin mRNA species are present in rat brain, a dominant neuronal species and two minor ones all of which were found to be developmentally regulated. Recent *in situ* hybridization studies in brain sections have shown that the level of tubulin expression is different in various cells of cerebellum. Furthermore, immunohistochemistry studies demonstrated that different microtubules are localized in individual cerebellar cells.

A molecular genetic approach to the study of catecholamines (neurotransmitters) was presented by J. Mallet (Laboratoire de Neurobiologie Cellulaire et Moleculaire, Centre National de la Recherche Scientific, Gif-sur-Yvette, France). Mallet, who is a very productive and first-class young scientist emphasizing the use of rDNA techniques in neurobiology research, discussed some of his continuing work on catecholamines. These compounds are an important class of neurotransmitters in the central and peripheral nervous system. They constitute a useful model for the analysis of the mechanisms involved in the regulation of gene expression during development. Tyrosine hydroxylase (TH) the rate-limiting enzyme in the synthesis of catecholamines has been intensively studied because of its key role in the physiology of adrenergic neurons. The regulation of its expression is under developmental control and its synthesis can be induced *in vivo* by nerve stimulation or by treatment with reserpine. Mallet deduced the entire amino acid sequence of rat and human TH from the nucleotide sequence of the cDNA clones he prepared. He was able to prepare microgram amounts of rat TH mRNA by rDNA methods. This mRNA, after microinjunction into *Xenopus* (frog) oocytes, produced TH which was biologically active. Thus, the post-translational modifications which are required for the full activity of the enzyme can be analyzed.

As a model to study the trans-synaptic induction of the TH enzymes, rats were injected with a single dose of reserpine and the time/course changes of both TH mRNA and enzyme activity were analyzed in rat adrenals and in two brain areas (locus coeruleus [LC] and substantia nigra). Reserpine caused an increase of TH mRNA in adrenals and LC. Mallet has also carried out *in situ* hybridization studies for the detection of specific mRNA's at the cellular level. Furthermore, Mallet has isolated the TH nuclear gene from a rat cosmid library, analyzed, and introduced this gene into mouse neuroblastoma and hamster glial cells, which do not produce detectable levels of TH mRNA. He found that transcription and translation of the TH gene occurred in the transfected cells. This approach will be very useful in assessing the functional role of sequences preceding the coding portion of the genome. Mallet was also able to assign the human TH gene to chromosome 11 and found that the digestion of human cellular DNA with restriction enzymes yielded a suitable marker for linkage studies involving the TH gene. Utilizing this approach, Mallet is trying to identify the DNA sequences responsible for the abnormal phenotypes for the autosomal dominant form of Alzheimer's disease.

Using rDNA methods, A. Dautigny, P.M. Alliel, M.G. Matter, D. Pham-Dink, and P. Jolles (Protein Laboratory, CNRS, U.A. 118, University of Paris, V, France) presented their very interesting work on the molecular cloning of mRNA coding for rat brain myelin proteolipid protein (PLP). The role of the myelin proteins--i.e., myelin basic protein (MBP) and PLP--in demyelinating diseases such as multiple schlerosis is under intensive investigation in many laboratories. The molecular biological approach being used by Dautigny et al. should provide information at the molecular level.

Dautigny et al. were able to prepare PLP cDNA and to sequence the nucleotides comprising the cDNA, thereby obtaining the derived amino acid sequence of PLP. They found that the structure of PLP was highly conserved during evolution with only three differences found between rat and human PLP sequences. They also observed that PLP does not require a signal peptide sequence for insertion into the myelin membrane. Using *in situ* hybridization with the PLP cDNA probe, the PLP gene was localized to human chromosome x as well as to mouse chromosome x. This localization may have implications for x-linked human myelin disorders. In mouse, Dautigny et al. found that the sex-linked recessive mutation, *jimpy*, is located in the structural gene coding for PLP.

Exciting results on the molecular cloning of a new glia-derived, recently isolated promoting factor (GdNPF) was reported at the meeting by S. Gloor, J. Guenther, H. Nick, R. Meier, J. Sommer, and D. Monard (Friedrich Miescher Institute, Basel, Switzerland). The GdNPF, a 43-kilodalton polypeptide had been purified to homogeneity from medium conditioned by C_6 rat glioma cells. Gloor et al. have found that this factor is a potent serine protease inhibitor. A rat cDNA clone with a sequence coding for GdNPF was isolated by hybridization-selected transcription using rabbit anti-GdNPF polyclonal antibodies. The amino acid sequence from rat GdNPF was deduced from the nucleotide sequence of the isolated cDNA clone. Gloor et al. observed a postnatal regulation of the GdNPF gene during rat brain development.

Immunological Approaches to Study Synapses and Development of the Nervous System

A.C. Cuello (Department of Pharmacology, McGill University, Montreal, Canada), who has been applying hybridoma technology to investigate transmitter specific neurons in the peripheral and central nervous system, has developed two new methods for application to such studies. One method is based on the use of internally labeled monoclonal antibodies (Mabs). A labeled amino acid, usually lysine, is added to the hybridoma and becomes incorporated into immunoglobulin (IgG). In this way, Cuello was able to obtain a probe of high specific activity that is stable for up to 2 years. This method allows the demonstration of antigenic sites by light and electron radioautography. The second method makes use of bispecific Mabs, a product of hybrid-hybridomas (e.g., substance P plus peroxidase). This method permits the immunoenzymatic demonstration of antigenic sites using a single IgG (bispecific Mabs).

Characterization and distribution of a new cholinergec-specific antigen, which they have termed Chol-1, was reported by E. Borroni, P. Ferretti, and J. Obrocki (Department of Neurochemistry, Max Planck Institute for Biophysical Chemistry, Göttingen, West Germany). This antigen was first isolated from the cholinergic electromotor nerve terminals of the electric organ (EO) of *Torpedo mamorata*. Antiserum to Chol-1 also recognizes mammalian cholinergic terminals. Chol-1 was found to be gangliosidic in nature. Affinity-purified antiserum to Chol-1 was used to study its immunohistochemical distribution in rat CNS. The results obtained indicated the existence of two polysialogangliosides bearing antigenic determinants specific for the cholinergic system.

A.L. De Blas (Department of Neurobiology and Behavior, State University of New York, Stony Brook) presented a very interesting report on the use of Mabs to isolate an endogenous benzodiazepine from mammalian brain. This material was isolated from bovine brain and purified to homogeneity by immunochromotography on immobilized Mab 21-7F9 (benzodiazepine-specific) followed by three chromatographic procedures. The purified substance has been identified as N-desmethylbenodiazepam. De Blas found that this material is present in human and other mammalian brains. However, he doesn't know yet whether natural benzodiazepines are biosynthesized by mammals or if they may be taken up by neurons from the diet--i.e., from administration of these compounds to animals used for food.

Neurotransmitters and Peptides in Stress

The aim of the workshop on this subject was to analyze the role of brain and peripheral catecholomines (nonadrenaline, adrenaline, and dopamine) of brain serotonin and histamine and of enkephalins in neuroendocrine processes under stress in rat and man. It appears that understanding of the exact mechanisms of the stress response is considerably complicated by the fact that monaminergic and peptidergic systems interact in the control neuroendocrine responses under stress.

Studies on the brain noradrenergic system in stress were discussed by T.I. Belova and P.K. Anokhin (Institute of Normal Physiology, USSR Academy of Sciences, Moscow). Belova has found that the LC has a regulatory influence on blood brain barrier (BBB) function and the integrity of brain vessels. Since the formalis reticularis mesencephalon (FR mes) is the structure involved in many kinds of adaptive functions (homeostatic and behavioral) Belova has suggested that emotional stress leads to a deficiency of the organism's adaptive function in the following way: emotional stress → LC hyperfunction → changes in brain energy metabolism → ruptures of brain parenchymal vessels and as a consequence of these events → damage of nerve and glial cells (especially in the FR mes) → disturbance of the organism's adaptive capacity.

Yet another transmitter system in stress, namely, the serotoninergic system, was dealt with by J. Culman, P. Zeman (Institute of Experimental Endocrinology, Bratislava, Czechoslovakia), and C. Chiueh (National Institute of Mental Health, Bethesda, Maryland). Turnover of brain serotonin (5-HT) reflects the functional state of the 5-HT system and involves many reactions; e.g., synthesis, degradation, precursor availability, etc. All these factors are involved in the regulation of the 5-HT system in stress conditions. These investigators found that acute stress increases the 5-HT levels in several brain areas. Studies of the various reactions of the 5-HT system demonstrated the increased turnover of 5-HT in the brain, presumably due to an increase in the release of 5-HT from the nerve terminals during acute stress.

In a different approach, F. Berkenbosch and P.J.H. Tilders (Department of Pharmacology, Medical Faculty, Free University, Amsterdam, The Netherlands) studied the effect of insulin-induced hypoglycemia on the turnover of corticotropin-releasing factor (CRF) and vasopressin (VP) in the median emmesence (ME) of the rat. The study was based on the known effect of this hypoglycemia in stimulating pituitary adrenocorticotropin (ACTH) secretion in animals and man. These researchers found that (a) hypoglycemia enhances the secretory activity and thereby the turnover of CRF and VP neurons terminating in the ME and (b) VP and CRF released from their nerve terminals are rapidly replenished by fast axonal transport.

Another type of stress (injection of Newcastle disease virus [NDV]) and the response of catecholamines and plasma corticosterones was studied by A.J. Dunn and M.L. Powell (Department of Neurosciences, University of Florida, Gainesville). They found significant increases in catecholamine catabolites in the brains of both intact and hypophysectomized rats after NDV injection. Plasma corticosterone levels were increased only in intact rats. The results suggest the brain responds to an antigenic challenge (stress) to the immune system and may involve immune defense mechanisms.

T. Sourkes (Department of Psychiatry, McGill University, Montreal, Canada) presented data on the central regulation of the sympathoadrenal system in animals under stress. He found that induction of tyrosine hydroxylase (TH), the rate-limiting enzyme in catecholamine biosynthesis, is formed by activation of a dopaminergic system in the A9 region of the brain and is retarded by serotonergic fibers emanating from the medial raphe nucleus. In contrast, β-hydroxylase (DBA) induction, which also occurs in the stressed rat, entails reduction of both catecholamines and serotonin, as seen in the reserpinized animal or those given a combination of α-methyltyrosine and p-chlorophenylalanine. DBH, like TH, is also inducible through a central muscarinic action, and this induction is ameliorated under the influences of GABA agonists.

A detailed study on the role of the adrenomedular-pituitary axis in the control of the pituitary response to stress was presented by F.H. Tilders, F. Berkenbosch and I.D. van Zoest (Department of Pharmacology, Medical Faculty, Free University, Amsterdam). Peripheral administration of epinephrine (EP) was found to increase the circulating concentration of various stresslike hormones (prolactin, ACTH, β-endorphin, α-melanocyte-stimulating hormone) to levels seen during stress. These effects were mediated by β-adrenoreceptors and are of physiological significance. Thus, it appears that catecholamines released from the adrenal medulla are involved in the release of hormones from lactotroph and melanotroph cells during emotional stress.

G.R. van Loon, K. Pierzchala, L. Brown, S. Moussa, P. Zeman, and R. Kvetnamsky (Department of Medicine, University of Kentucky, Lexington), and the Institute of Experimental Endocrinology, Center for Physiological Sciences, Academy of Sciences, Bratislava, Czechoslovakia) reported on an *in vivo* study of stress-induced secretion of sympathoadrenal opioid peptides and catecholamines in two animal models (rats and dogs). They found that stress (immobilization) stimulated the secretion of proenkephalin A derived opioid peptides in both animal models. Repeated stress in the rat appeared to be associated with adaptation of the met-enkephalin response with decreased release but increased synthesis or processing of adrenal met-enkephalin.

Conclusion

The greatly increased use of molecular biological techniques to investigate problems in neurobiology which can not be approached with conventional biochemical methods was very much in evidence in the presentations at the sixth meeting of the ESN. Immunological approaches also received a great deal of attention. The effect of stress of various forms on catecholamines and neuroendocrine hormones was also emphasized. Studies of neurogenesis, the role of gangliosides and disease states of the nervous system were also covered at this meeting.

It is evident that European neuroscientists are carrying out first-class research and, as seen in some of the elegant studies presented in this report, have also begun to emphasize the use of molecular biology techniques.

10/16/86

Chemistry

INTERNATIONAL SYMPOSIUM ON HIGH-TEMPERATURE CORROSION

by Robert L. Jones. Dr. Jones is the head of the High Temperature Chemistry Section, Chemistry Division, Naval Research Laboratory, Washington, DC.

The International Symposium on High-Temperature Corrosion of Materials and Coatings for Energy Systems and Turboengines was held from 7 through 11 July at the Université de Provence in Marseilles, France, under sponsorship of the university and the Electric Power Research Institute (EPRI [US]) with financial aid from French industry and government agencies. This was a major conference organized by Professor R. Streiff (Université de Provence) and Professor J. Stringer (EPRI), with an Advisory Committee that included virtually every prominent name in high-temperature corrosion science. Of the approximately 150 attendees, the greatest number were French, but there were sizeable contingents also from the US, West Germany, the UK, the Netherlands, and Japan, and representatives from nearly every European nation (including Poland and Yugoslavia) as well as Israel, Canada, and Australia.

The conference was intended to promote interaction and exchange of knowledge--which in the past has too often been lacking--between researchers in different parts of the world, and in different high-temperature technologies (i.e., steam generation, coal conversion, industrial processing, gas turbines, nuclear reactors). For this reason, the oral presentations (about 70 in number) contained many plenary and keynote lectures by recognized leaders in different areas of high-temperature corrosion science/technology which were meant to broaden the understanding of an audience which, although knowledgeable, might not be expert in given, specific fields. The conference also included poster presentation sessions where the papers, of which there were also about 70, mostly emphasized new experimental results. A proceedings of the conference, which will consist of the oral presentations and selected poster papers, is scheduled for publication in early 1987 in *Materials Science and Engineering*.

The conference was organized into 10 themes which ranged from, first, high-temperature gaseous oxidation to, tenth, performance experience of coatings in practice--a progress approximating "science transitioning to technology." A number of the papers are described below, the selection based probably as much on my own interests and comprehensions (many of the principal papers were given in French, which I do not speak) as on merit.

Gaseous Oxidation

Emphasis in this area was on sulfidation (i.e., oxidation by S) and dual-oxidant (e.g., O_2+SO_2) attack. P. Kofstad (University of Oslo, Norway) explained accelerated oxidation of nickel at 600 to 850°C by O_2+SO_2 as occurring because of a duplex mixture of NiO and $Ni_{3\pm x}S_2$ forms on the nickel surface, with the $Ni_{3\pm x}S_2$ phase providing a path for rapid outward diffusion of nickel. Attack tends to be reduced above 800°C as the $Ni_{3\pm x}S_2$ phase becomes unstable, or by small additions of Si, Fe, or Mn, which segregate to the NiO grain boundaries (e.g., as silicates) and disrupt the sulfide channels.

The sulfidation at 400 to 1100°C of Mn, Nb, and Mn-Nb (these metals being known for sulfidation resistance) was shown by S. Mrowec (Academy of Mining and Metallurgy, Krakow, Poland) to proceed by volume diffusion (as Mn^{2+} cations and electron holes) in the coarse-grained scale formed above 725°C, and by grain boundary diffusion in the fine-grained scale produced below 525°C.

The diffusional growth of multiphase scales and subscales on binary alloys and the role of point defects in oxide scales in oxidation behavior--both fundamental aspects in oxidation--were addressed by W. Smeltzer (McMaster University, Ontario, Canada) and F. Gesmundo (University of Genoa, Italy) in papers too detailed to be easily digested in a single lecture, but which will be valuable reviews in the published proceedings.

Growth and Adherence of Protective Oxide Scales

This topic was vigorously discussed, as might be expected since it is a critical factor in producing corrosion resistant high-temperature materials. Review papers were presented by F. Stott (University of Manchester, Institute of Science and Technology [UMIST], UK), who dealt principally with stress development during the growth process as a cause for oxide adherence failure, and by G. Beranger (Université de Technologie de Compiègne, France), who spoke about both the causes of oxide adherence failure and the ways of measuring residual oxide stress (x-ray diffraction, curvature of specimens oxidized on only one side) and oxide adherence (mechanical fracture, scribe tests, *in situ* vibration frequency, electrical resistivity, or acoustic emission measurements).

The role of yttrium in improving oxide scale adherence, always a popular topic, was the subject of several papers. J. Smeggil (United Technology Research Center, US) presented evidence that yttrium forms refractory phases with sulfur, and thus immobilizes trace (50 to 100 ppm) sulfur in the metal which otherwise would segregate to, and weaken the bond at, the oxide scale/metal interface. On the other hand, A. Huntz (Université de Paris Sud, France) concluded, from results of their studies and the literature, that small additions of yttrium modified plasticity and retarded oxygen diffusion in alumina oxide scales, with both effects possibly improving oxide adherence.

Y. Saito (Tokyo Institute of Technology, Japan) found improvement of oxide adherence on Ni-20Cr-1Si with 0.5 percent additions of Ce, La, or Er as well as Y, which was explained as a "keying-on" effect resulting from growth of oxide protrusions into the metal. The effect of yttrium must therefore be considered as still uncertain (as must numerous other questions in oxide growth and adherence), but progress is clearly being made as more sophisticated analytical techniques are applied.

Corrosion by Molten Salts

This topic, which includes, for example, gas turbine hot corrosion and molten salt-induced corrosion on boiler firesides and in fluidized bed combustors, began with a plenary lecture by R. Rapp (Ohio State University), who reviewed findings made largely by his group at Ohio State concerning the chemistry and electrochemistry of molten salt corrosion. Their measurements of the acidic and basic solubilities of different turbine metal oxides (NiO, Co_3O_4, Fe_2O_3, Al_2O_3, Cr_2O_3, and others) in molten Na_2SO_4 have had wide impact in the hot corrosion field, both in explaining observed hot-corrosion behavior and in developing an understanding of acidic-basic reactions in molten salt corrosion.

Notable review-type papers were also presented by A. Rahmel (Dechema Institute, West Germany; given by M. Schutze on behalf of Professor Rahmel, who was ill) on molten salt electrochemical corrosion reactions, and by K. Luthra (GE, Schenectady, New York) on low-temperature hot corrosion. For corrosion by molten vanadates, E. Chassagneux (École Nationale Superior de Mines, France) showed the 900°C oxidation of nickel coated with V_2O_5 to be dependent on the O_2 partial pressure, with maximum oxidation rate observed at 2×10^4 Pa of O_2. R. Jones (Naval Research Laboratory) delineated the reactions occurring when Co-Cr-Al-Y is corroded at 700°C by molten sulfate-vanadate deposits under low SO_3 partial pressures.

This topic session also included a well-received plenary lecture by M. Pourbaix (Centre Belge d'Étude de la Corrosion [Cebelcor], Belgium) who presented numerous examples (e.g., for systems such as O-H-Fe, O-S-Fe, O-S-Al) illustrating that high-temperature equilibrium reactions can be readily predicted from thermochemical diagrams (commonly called "Pourbaix" diagrams--obtained from Professor Pourbaix's many years of work).

Ceramic Corrosion Performance

Although ceramic components and coatings hold promise for heat engine applications, problems with oxidation (for non-oxide ceramics) and molten salt corrosion remain unsolved. In discussing the oxidation of SiC and Si_3N_4 (which depend on formation of a protective SiO_2 outer film for oxidation resistance) M. Billy (Université de Limoges, France) pointed out that the oxidation kinetics were more affected by the mechanical properties of the SiO_2 surface film than its chemical properties (i.e., stability with respect to O_2 partial pressure).

S. Forseth (I.K. Engineering, Oslo, Norway) described failure mechanisms of stabilized ZrO_2 coatings in diesels, and noted that for failure induced by use of fuel containing both S and V, the reaction leading to destabilization (and failure) produced YVO_4 with Y_2O_3 stabilized ZrO_2, but $CaSO_4$ or $MgSO_4$ with CaO or MgO stabilized ZrO_2; this parallels early results in "vanadium treatment" of V,S-containing fuel where MgO or CaO additions reacted preferentially to produce the sulfate rather than the desired refractory Mg or Ca vanadate.

The effect of processing on the corrosion resistance and thermal response of plasma-sprayed stabilized zirconia coatings was reviewed by H. Herman (State University of New York, Stony Brook), who stressed that high homogeneity of the plasma-spray powder, and obtaining of the proper crystal structures, were vital in achieving good performance.

Coating Technology

This was the largest topic theme, touching on the effects of composition and microstructure on coating performance, elucidation of additive (Pt, Si) effects, influence of coatings on substrate mechanical properties, development of silicide and alternate coatings, laser surface alloying, and numerous other subjects. As such, it is difficult to review and the reader is referred to the proceedings to be published; however, one point of enlightenment which I wish to share was made by Y. Lindblom (FFV Materials Technology, Linköping, Sweden), who noted--concerning the "new" M-Cr-Al-Y coating alloys--that Fe-Cr-Al-Y was available in 1926 under the name Kanthal.

Conclusion

This conference achieved its goals of promoting intercourse between what might be described as the English-speaking and French-speaking schools of high-temperature corrosion science, and between the groups associated with the different high-temperature technologies. The first goal was aided by the setting of the conference at the Université de Provence, by usage of both French and English language presentation, and by the excellent French food served at the conference luncheons and at the superb evening banquet in the beautiful resort city of Cassis. The second goal benefitted from strong support from the technology/science communities in many nations which insured high-quality representation at the conference for the different fields of high-temperature corrosion science. No plans for future symposiums were given, but further conferences of this type should be encouraged.

10/16/86

Computer Sciences

THE EUREKA PROGRAM

by J.F. Blackburn. Dr. Blackburn is the London representative of the Commerce Department for industrial assessment in computer science and telecommunications.

Background

EUREKA (European Research Coordination Agency) grew out of a proposal made in 1985 by President Mitterand of France. As described in its declaration of principles, "The objective of EUREKA is to raise, through closer cooperation among enterprises and research institutes in the field of advanced technologies, the productivity and competitiveness of Europe's industries and national economies on the world market, and hence strengthen the basis for lasting prosperity and employment. EUREKA will enable Europe to master and exploit the technologies that are important for its future, and to build up its capability in crucial areas. This will be achieved by encouraging and facilitating increased industrial, technological, and scientific cooperation on projects directed at developing products, processes and services having a worldwide market potential and based on advanced technologies. EUREKA projects will serve civilian purposes, and be directed both at private and public sector markets." (See *ESN* 39-12:570-574 and *ESN* 40-4:141-142 for previous articles on EUREKA.)

The initial emphasis of EUREKA is on information and telecommunications, robotics, materials, manufacturing, biotechnology, lasers, environmental protection and transport technologies. The first 10 EUREKA projects were adopted during the second ministerial meeting held in Hannover on November 5-6, 1985. A further 62 projects were adopted during the third ministerial conference held in London on 30 June 30 1986. Between these two ministerial meetings many of the 62 new projects were formally presented during technical meetings--15 in London in January 1986 and a further 24 in March. Thus, 72 projects have received formal ministerial approval as of 30 June 1986.

The declaration of principles of EUREKA says that EUREKA projects are not intended as a substitute for existing European technological cooperation or its further development. Their purpose is to extend or supplement this cooperation. The European Communities participate as partners in EUREKA, as do its member states individually. Membership is, however, open to all Western European countries and its membership now stands at 18.

The EEC programs--Basic Research in Industrial Technologies for Europe (BRITE), European Strategic Program for R&D in Information Technologies (ESPRIT), and R&D in Advanced Communication Technologies for Europe (RACE) (*ESN* 39-7:344-346 [1985])--operate within the strict framework of Europe and the EEC and at the precompetitive stage. In principle, research carried out within ESPRIT, RACE, or BRITE could become the basis of a EUREKA Project to be carried forward to the marketing stage. The EUREKA Advanced Software Technology project, for example, is the industrial continuation of the ESPRIT (*ESN* 40-11/12:411-414 [1986]) Portable Common Tool Environment (PCTE) project and other ESPRIT projects.

Since BRITE is a program to accelerate the use of new technologies in traditional sectors, its topics will often coincide with those considered by EUREKA (*ESN* 39-12:570-574 [1985]). Following a call for bids in 1985, 95 projects were selected for BRITE. Another call for bids was issued in April 1986 from which further BRITE projects will be selected in early 1987. Thirty-one contracts in the RACE program were signed in April 1986. This program is designed to carry out the research necessary for creation by 1995 of an extensive broadband European telecommunications network.

EUREKA Projects

Following are brief descriptions of the 10 projects approved at Hannover in November 1985: (Sixteen projects were listed by title in *ESN* 40-4:141-142 [1986]).

1. Compact vectorial computer. The firms Matra, France, and Norsk Data, Norway, are to develop a 100-MFLOP-capacity minicomputer offering a much better cost/performance ratio than that of present-day large systems. The plan is to offer within 5 years superminicomputer machines similar to present machines in price, size, energy consumption, and ease of use but 10 times more powerful. The development cost will be about $40 million over 5 years.

2. High-power lasers. Four countries, Britain, France, Italy, and West Germany, have joined forces to conduct research on the three kinds of high-power lasers: CO_2, YAG, and excimer lasers. The project is in the definition phase because it is very complex. It is to be developed over 5 years at a cost of about $50 million. The CO_2 laser program will be directed by the Marcoussis Laboratories, France, in conjunction with the German DFVLR (R&D Institute for Space Travel). The objective is to develop 30-kW hardware.

The French Quantel Company is to develop a solid YAG laser with power of the order of 3 kW within 5 years. The excimer lasers could be developed by the French company Sopra or the French company Cilas. Due to the present North American dominance in this market the excimer laser may not be developed in this project.

3. A flexible laser workshop. This computer-integrated manufacturing project will cost over $60 million over 5 years. The project will be supervised by Compagnie Generale de Productique. Five innovations will be developed: the CO_2 laser robot, the YAG laser robot, a laser-guided automatic trolley, an assembly robot with laser positioning, and an optical fiber local area network. Participating in the project will be Compagnie Generale d'Électricité (CGE), Fiat and the Swiss company SMH, whose subsidiary, LASAG, specializes in YAG lasers.

4. An integrated textile workshop. The project, under the name Textile Robot, is directed by Lectra Systems in Bordeaux and the Portuguese research centers, the National Laboratory of Engineering and Industrial Technology and IVBI (a research center specializing in textile industries). A 600-W CO_2 laser will permit the study of laser-fabric interaction phenomena. The final objective is an automated clothing factory.

The cost of development will be about $15 million over 5 years.

5. Amorphous silicon production. This project joins Solems (France) and the German company MBB. Solems has studied amorphous silicon for photocells, and MBB has specialized in crystalline silicon technology. The two companies will work together on the definition and development of an amorphous silicon production line with a capacity of 1 mW. The cost of the project will be about $40 million over 5 years.

6. Supermembranes for water treatment. The French company Lyonnaise des Eaux and the Dutch company De Danske Sukkerfabrikker intend to develop new membranes and new ultra- and microfiltration modules for water treatment. The target markets are for waste-water treatment, desalination, and production of drinking water and ultrapure water for electronic industries. The cost of the effort will be about $40 million over 5 years.

7. Environmental control. The project involves 10 European countries, with West Germany and France taking the lead. The project, concerned with atmospheric pollution, will have a 2-year definition phase to be followed by 5 to 7 years of evaluation and finalization of operations. The cost will be about $60 million.

8. Medical diagnosis. Britain and Spain have formed a partnership to develop biological diagnostic kits for sexually transmissible diseases. Methods using monoclonal antibodies will be implemented. Biokit SA (Spain), and PA Technology (UK) will spend about $2.25 million over 3 to 5 years.

9. Educational computer. Acorn (Britain), Thomson (France), and Olivetti (Italy) will work together to develop a personal computer for educational purposes. The cost will be about $40 million over a 3-year period.

10. Research coordination. West Germany, France, the EEC, and most other EEC countries will collaborate on creating a European telecommunications network for research workers for the exchange of data and services. The cost will be about $2 million for the definition stage covering a 1-year period. This could then be followed by a 5-year program for implementation.

Prominent among the 62 projects announced during the third ministerial conference on 30 June 1986 were development of:

- An expert system for dealing with major plant failures and security control
- A wideband interconnection module to form the basis of a future wideband integrated services digital network (ISDN) capability
- A flexible, automated factory for electronic cards, including the preparation of circuits and quality control of products
- Automatic design and production of custom chips using direct printing on silicon
- Integrated circuits--design and manufacturing processes for GaAs monolithic microwave integrated circuits
- Automatic production management system using AI developments
- An all-dry single-layer photolithography technology for submicron devices
- Sub-0.1-micron ion projection
- ADA realistic software workshop for real-time applications.

Assessment and Comments

The EUREKA program is largely civilian in its objectives, contrary to some early speculation. It is billed as a development effort to take research concepts to the stage of marketable products. Thus it is supposed to carry the work of precompetitive research programs like ESPRIT, RACE, and Alvey to the market. However, the second phase of both ESPRIT and Alvey in the preliminary descriptions seems to be product development more than research. If this proves to be the case then there will be substantial duplication among these programs. Also, RACE appears to be product-oriented in the telecommunications field.

Nevertheless, EUREKA has caught on among the governments and the companies of Western Europe. It has been referred to as Europe's technological rebirth. To get agreement on 72 projects, each involving several countries, in a period of 8 months is quite an achievement. The choice of projects covers a very wide spectrum of civilian technology, and most of the projects are well chosen in the sense of being designed to meet a real market need.

Coordination appears to be a weak link in the program. Only a very small coordination group, to be located in Brussels, is planned. However, many of the projects involve only two companies and in some cases companies that have worked together before. Furthermore, there is no centralization of financing as is the case in ESPRIT, RACE, and BRITE. Thus the coordination problem is diminished in EUREKA. Whatever government financing takes place will come from the countries directly involved in a given project rather than from a central organization, so the international organization of EUREKA is minimal and ill-defined.

The initial positive reaction of governments and companies to this program is far greater than even the French expected. There is a perceived need, partially nurtured by earlier EEC programs, for cooperative European effort to regain success in world marketing. The Europeans seem to realize that they must cooperate to produce products that will sell in world markets. With this sort of thinking and commitment of resources, the EUREKA Program should not be dismissed as a potentially interesting scheme. It is, in fact, a real live program with a reasonable chance of having an important impact on Europe's competitiveness in 5 to 10 years.

10/1/86

Mechanics

AERODYNAMICS AND ENERGETICS AT ONERA

by Eugene F. Brown. Dr. Brown is the Liaison Scientist for Fluid Mechanics in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on leave until September 1987 from the Virginia Polytechnic Institute and State University, where he is a Professor of Mechanical Engineering.

Background

ONERA, the French National Institute for Aerospace Research and Studies, was founded in 1946 to "develop, orient, and coordinate research in the field of aeronautics." Today ONERA employs 2100 people, over two-thirds of whom are scientists and engineers. ONERA makes contributions in the areas of fundamental and applied research and renders technical assistance when called upon by the aerospace industry.

The first day of my 2-day visit was spent in ONERA's Aerodynamics Department at Châtillon and Chalais-Meudon; the second day was spent in ONERA's Energetics Department, located in Palaiseau. Châtillon and Chalais-Meudon are southwest Paris suburbs and Palaiseau is an outlying community located approximately 15 km southwest of Paris.

My visit to the Aerodynamics Department was hosted by Dr. J.M. Délery, who is the head of the Fundamental Aerodynamics Branch, which is one of the six groups in which the Aerodynamics Department is divided. The other branches with their heads indicated in parentheses are:

- Experimental Aerodynamics (J.-P. Chevallier)
- Applied Aerodynamics (B. Monnerie)
- Theoretical Aerodynamics 1 (P. Morice)
- Theoretical Aerodynamics 2 (Y. Morchoisne)
- Theoretical Aerodynamics 3 (J.-C. Le Balleur)

In the Aerodynamics Department approximately 50 percent of the research is funded through the ONERA budget and 50 percent from contracts from such aerospace industries as MATRA and Aérospatiale or government agencies such as DRET (the Directorate of Armament Research, Studies, and Techniques). Additional information on many of the investigations which I will subsequently describe are contained in the ONERA annual reports (*Activities* 1984 and 1985) as well in the specific references to which I refer in the following paragraphs. I have copies of all of these references and others which I would be happy to supply upon request.

Experimental Aerodynamics

The Experimental Aerodynamics branch has six major research wind tunnels covering the speed range from low subsonic at atmospheric pressure to hypersonic at more than 100 atmospheres. These tunnels are located at Chalais-Meudon and are jointly used by the theoretical and applied aerodynamics research groups at ONERA and the European aerospace industry.

The largest facility is the atmospheric Eiffel-type (open return) S-2 wind tunnel which has been in operation since 1964. The maximum speed of this wind tunnel is 100 m/s, and the test section is 3 m in diameter and 5 m long. Mounted in the tunnel on the day of my visit was ONERA's three-component laser Doppler anemometer (LDA) system designed by Boutier (*ESN* 40-8:268 [1986]) which uses two 15-watt argon ion lasers and can be operated in either forward or backward scan. Both the transmitting and receiving optics are mounted on independent computer controlled platforms. The entire system cost approximately $1 million, and the branch is currently building a second system.

The S-5 tunnel is a supersonic, closed-circuit, atmospheric tunnel with two test sections. The first test section is of conventional design having a cross section of 0.3×0.3 m^2 and a Mach number which can be varied from 0.8 to

3.12. This was recently used for the design and calibration of a miniature (1.5-mm diameter) 5-hole velocity probe for turbomachinery applications. The second test section has a cross section of nominally the same size, is a supersonic tunnel (M=1.2), but has adaptive rather than conventional walls. Unlike subsonic, adaptive-wall wind tunnels, this supersonic test section has a segmented lower wall consisting of individually adjustable 2-mm-wide vertical steel laminates rather than a continuous wall such as is found in subsonic, adaptive-wall wind tunnels. This is because the interference produced by the shock waves found in supersonic flow can only be cancelled by walls of discontinuous curvature.

The R-3 wind tunnel is one of three hypersonic wind tunnels operated by the branch. It is of open-jet, blow-down type with a 0.33-m-diameter test section, a Mach number of 10, and operates at a pressure of 120 atmospheres. In this facility forces are measured with a six-component balance. Surface heat flux is measured by means of thermosensitive paint, surface thermocouples, and thermocapacitive heat-flux meters.

No description of ONERA's experimental facilities would be complete without mention of H. Werlé's world-famous vertical water tunnels. These low-speed (0.65 to 0.15 m/s) gravity-fed tunnels have test sections which range from 0.22×0.22 m^2 to 0.8×0.8 m^2. These tunnels have been used for more than 20 years to make flow visualization studies of a wide variety of flows ranging from simple bodies at angle-of-attack to helicopters where the tip vortices, engine, inlet flows, and engine exhaust jets are simultaneously visualized (Gallon, 1986; Werlé, 1986). Films showing tests being conducted in these facilities are also available (*Activities*, 1986).

Fundamental Aerodynamics

The work of this branch (headed by Délery) is to plan and carry out experiments related to basic fluid mechanics phenomena of aerodynamic interest. The experimenters often use the facilities just described as well as several smaller blow-down facilities specifically designed for investigations such as Délery's well-known shock wave/boundary layer interaction studies (Benay et al., 1986). Typical of current work being done in this branch is the study by Pagan and Solignac (1986) of vortex breakdown produced by an adverse pressure gradient. In these tests a vortex is produced by a 75° sweep-angle delta wing mounted at an attack of 20°. The vortex is visualized by a light-sheet technique and mean velocity measurements were made with a five-hole probe. In addition, ONERA's three-component LDV system was used to make mean and fluctuating velocity measurements in two meridional planes. Typical results are shown in Figure 1 where the three components of vorticity are plotted in the meridional plane in the vicinity of vortex breakdown.

Délery's group is also involved in the evaluation of codes developed by ONERA and others in order to examine the accuracy and the limitations of existing computer codes and the adequacy of various turbulence models by comparing their performance with experimental results. A good example of this work was presented at the Colloquium on Turbulent Compressible Boundary Layers in Poitiers (*ESN* 40-8:286 [1986]).

Another interesting study was the calculation of turbulent separated flow for a family of ellipsoids using the technique of Formery (Barberis, 1986). This method, which requires experimental values of the wall shear-stress field, involves the coupling of an upstream direct calculation where the external flow velocity is prescribed to a downstream indirect calculation based on the measured wall-shear stress pattern. In this way a complete calculation of the flow over various ellipsoids is obtained which can be continued through the line of separation into the separated flow region. Given the relatively simple (mixing length) turbulence model which was used, the calculations were satisfactory; however, wider use of this technique might be limited because of the requirement for the measured values of the wall-shear stress.

There is also some direct simulation work going on in this group. It is being done by K. Dang and P. Loisel, who have published recent reports of this work (Dang, 1986; Loisel, 1986).

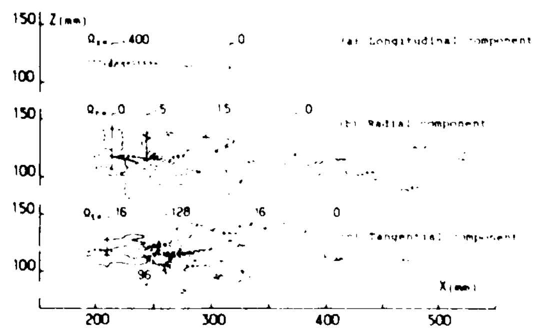

Figure 1. Vorticity: (a) Longitudinal component (b) Radial component (c) Tangential component.

Applied Aerodynamics

I received a short briefing from the Applied Aerodynamics Branch. The group comprises a staff of 44, headed by B. Monnerie, and is involved primarily in experiments conducted for the French government and the aerospace industry. The purpose of these experiments is often to provide information on the performance of various aircraft and missile systems, particularly for the purpose of configuration definition for advanced research projects. Figure 2 is an outline of the briefing I received which describes the most recent activities of the group. Additional information about most of these topics can be obtained from the ONERA 1984 and 1985 annual reports (*Activities*, 1984 and 1985). If you have a particular interest in any of these items I would be willing to obtain additional information directly from the individuals involved.

APPLIED AERODYNAMICS

<u>Combat Aircraft</u>
- Swept wing at high angle of attack
- Detailed studies of realistic configuration
- Advanced configurations
- Air intakes at high angle of attack

<u>Transport Aircraft</u>
- Airfoils
- High lift systems
- Wing/fuselage combinations in transonic
- Buffeting
- Drag reduction
- Wing/nacelle interaction
- High speed propellers
- Control surfaces

<u>Missiles</u>
- Air intakes
- Nozzels
- External aerodynamics
- Advanced configurations

<u>Helicopters</u>
- Airfoil design
- Rotor aerodynamics
- Air intakes
- Fuselages

Figure 2. Activities of Applied Aerodynamics Group.

Theoretical Aerodynamics 1

In Theoretical Aerodynamics 1, headed by P. Maurice, three-dimensional Euler calculations and two-dimensional Navier-Stokes calculations are being carried out. I was briefed on the two-dimensional calculations of supersonic cascade flows and shock wave/boundary layer interactions in a channel (Cambier et al., 1986). In the cascade calculations the Navier-Stokes equations were solved in the region near the blade and in the downstream wake, and the Euler equations, using the multigrid technique (Couaillier, 1985), were solved everywhere else. To accomplish this the computational domain is divided into 5 regions (see Figure 3). To link the calculations between zones, characteristic relationships are used at the interfaces. For the solution of both the Navier-Stokes and the Euler equations the explicit scheme of MacCormack was used. Near the wall, the grid was refined by using the dichotomy technique (Michel, et al., 1969). To simulate turbulence effects, Michel's mixing length model was used, but it was replaced by the law of the wall in the near-wall region. For increasing cascade back pressure, a progressively more normal shock pattern is produced, as would be expected, and the calculations show good smoothness across the subdomains, thus providing convincing indication of the proper operation of the compatibility relationships.

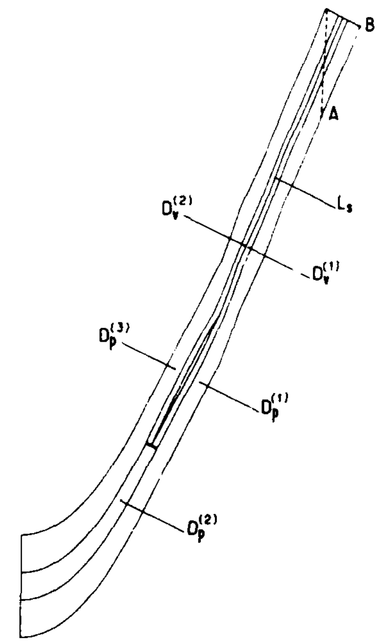

Figure 3. Subdomains for cascade calculations $D_v^{(1)}$, $D_v^{(2)}$, and L_s are Navier-Stokes subdomains; $D_v^{(1)}$, $D_v^{(2)}$, and $D_v^{(3)}$ are Euler subdomains; A-B indicates downstream boundary.

In the transonic channel test case, flow at a Mach number of 0.45 is incident on a bump located on the floor of the channel; the objective is to compare the predicted pressure mean and fluctuating velocity components with Délery's experimental data. Just as in the previous case, the dichotomy method was used to refine the grid near the wall. Eight zones of sub-griding were used. Calculations were run using both the previous mixing model and the k-ε turbulence model. The wall velocity profiles were more or less adequately predicted by both models, but the mixing length model predicted the reattachment length much more accurately. The k-ε model predicted a more accurate wall pressure distribution but did not succeed very well in predicting the wall turbulent kinetic energy profiles. In addition, the turbulent shear stress was not well predicted by either the k-ε or the mixing length models.

Theoretical Aerodynamics 2

In order to obtain a more rapid convergence rate, the staff of Theoretical Aerodynamics 2, headed by Y. Morchoisne, has developed an explicit/implicit method employing local time stepping. Using this technique they experienced a three to four factor of increase in speed compared with the earlier explicit calculations. Test cases have been conducted on a NACA-0012 airfoil and the flow in the base region of a nozzle afterbody using the Baldwin-Lomax algebraic mixing length turbulence model (Hollanders and Ravalason, 1986). The method comprises two computational stages. In the first one, provisional values are calculated by using an explicit predictor-corrector scheme, which is a generalization of the centered Thommen scheme. In the second stage the provisional values are corrected by implicit operators factored with the alternating direction implicit (ADI) technique. The missile afterbody results show good agreement with experiment, particularly in the case of the base pressure and the length of the zone of separated flow. A three-dimensional case involving flow over the ONERA M6 wing was also carried out.

Theoretical Aerodynamics 3

An approach offering even greater computational economy is offered by the so-called viscous/inviscid interaction methods. These are being pursued by Theoretical Aerodynamics 3, headed by J.-C. Le Balleur. His group consists of about 10 people who are working the problems of two-dimensional external/internal unsteady flows and three-dimensional flows over wing and slender bodies. Of particular interest is their investigation of buffet effects generated by transonic, shock-induced separation. These calculations employ a fully time-consistent, two-dimensional viscous/inviscid interaction method using a new "semi-implicit" method to produce a time-consistent coupling. The viscous effects are included by means of an unsteady defect integral method for attached or separated turbulent boundary layers; this is coupled with a transonic small perturbation (TSP) solver (Le Balleur and Girodroux-Lavigne, 1986).

For three-dimensional flows, Le Balleur's group has developed a multizonal marching (MZM) method (Lazareff and Le Balleur, 1986) which allows control over the viscous-inviscid interaction by computing the field of inviscid wall-transpiration velocities directly at the coupling notes. They have made calculations for transonic transport wings and for prolate spheroids at incidence (see Figure 4) and, in collaboration with MATRA,

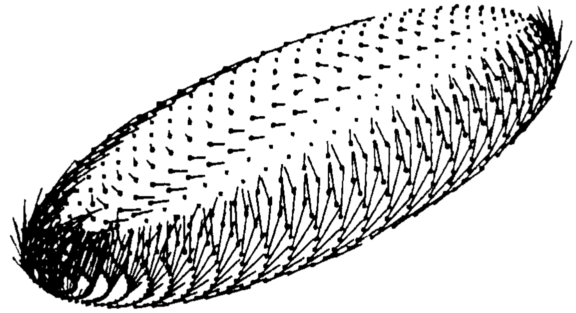

Figure 4. Wall shear stress vectors for a prolate spheroid at incidence (6:2:1 ellipsoid, 60° incidence, $Re=6.7\times10^{6}$).

are pursuing calculation of open, three-dimensional separation including the generation of vortex sheets. They have also done work in highly separated two-dimensional flows such as high-angle-of-attack performance of spoilers (Le Balleur, 1986). The group has run a number of other interesting, steady two-dimensional cases including the channel flow with a bump, a supersonic ramp, and a supersonic compressor cascade (Le Balleur and Blaise, 1986).

Calculations in a double-throated nozzle and a three-dimensional inlet were also made. In the case of the double-throated nozzle an interesting situation arose in which a converged solution could be obtained only when a turbulence model was used. The laminar case apparently had no steady-state solution. Such situations are not uncommon for laminar airfoil problems where unsteadiness due to vortex shedding occurs. This is the first time, however, I have seen such unsteadiness in the calculation of laminar internal flow.

Energetics Department

The Energetics Department is approximately the same size as the Aerodynamics Department (186 people in 1985) with about a quarter of the personnel in Châtillon and the remainder at the experimental facilities in Palaiseau. The division carries out computational and experimental research on turbomachinery and combustion for both aircraft and missiles. The department consists of two divisions: the Turbomachinery Division, headed by J. Fabri, and the Chemical Propulsion Division, headed by P. Kuentzmann. My visit was to the Turbomachinery Division.

The computational activity in turbomachinery appeared to centered around the three-dimensional Euler code developed by Veuillot in the Aerodynamics Department.

In this work, a complete turbine stage (stator and rotor) are modeled, and in recent work by Le Meur the effects of the motion of the rotor blade have also been included. Additional work has included the development of design methods for turbine blades, calculation of disk losses, and simplified models for the distorted inflow response of axial flow compressors (Billet et al., 1986).

Combustion problems pose significant computational difficulties because of the diversity of the temporal and spatial scales represented by the chemical and convective processes present in the flow. The chemistry alone poses a problem since turbomachinery and ramjet combustion systems operate in a regime between kinetically dominated and mixing dominated combustion, and thus neither a pure kinetic model nor an eddy breakup model is descriptive of the actual combustion process. ONERA has sponsored research on two alternative approaches to this problem: The probability density function (PDF) approach of R. Borghi and the coherent flame model of S. Candel.

The Turbomachinery Division has developed both explicit and implicit codes using the Borghi and Candel models. One example is the application of the three-dimensional explicit code to the calculation of the flow in a planar reversed-flow combustor (Borghi et al., 1985) and another is the use of two-dimensional implicit code for the calculation of the flow in a ramjet-like combustor with swirl and without swirl (Dupoirieux, 1986; Dupoirieux and Dutoya, 1986).

Conclusion

Given the broad scope of research being conducted in the Aerodynamics and Energetics Departments of ONERA, it was, of course, impossible for me in a 2-day visit to do any more than selectively sample their activities. Nevertheless, from what I saw, several research areas emerged in which ONERA has established a worldwide reputation. These areas include, to name just two: benchmark quality shock wave/boundary layer experiments, and viscous flow calculations by means of viscous/inviscid interaction. It was also obvious, as evidenced by the large number of references at the end of this article, that ONERA is one of the most prolific research laboratories in Europe. In addition, its young and productive staff have access to experimental and computational facilities which would be the envy of many US research laboratories. With such resources there is no doubt that ONERA will continue to play a vital role in European aerospace research in the years to come.

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10/20/86

VORTEX FLOW SYMPOSIUM

by Eugene F. Brown and F.M Murman. Dr. Murman is a Professor of Aeronautics and Astronautics at the Massachusetts Institute of Technology. He attended this meeting with support provided by the Office of Naval Research.

Introduction

The Joint US/European Vortex Flow Symposium was held in Stockholm, Sweden, from 1 through 3 October 1986; it marked the formal end of a 4-year collaborative project involving The Netherlands, Sweden, Germany, and the US. The purpose of the project was to produce experimental data of vortical flows which could be compared with the results of Euler calculations, particularly in the transonic flow regime. This collaborative activity, now known as the "International Vortex Flow Experiment on Euler Code Validation," was the result of discussions initiated by Dr. G. Drougge of the Aeronautical Institute of Sweden (FFA) in Stockholm, who, after the International Congress for Aeronautical Sciences (ICAS) meeting in Seattle in 1982, recognized the benefits of international collaboration in this area.

The collaboration has been highly successful. More than 40 scientists and engineers representing the participating nations, as well as observers from France and the UK, were present at the Stockholm symposium, and 19 separate presentations were made. The results of the symposium will be published in the form of an extended review of the topic sometime early in 1987. I have a collection of abstracts that were distributed in advance of the meeting which I would be happy to make available to anyone having an interest.

As L.B. Persson, the Director General of FFA, indicated in his opening remarks, this project represents an excellent example of what can be accomplished by international cooperation. The success of the activity depends upon finding a topic of common interest to the aeronautical research communities of the participating nations. Drougge, with considerable foresight in 1983, perceived that a combined computational and experimental program to better understand the flow over a delta wing would be such a project. Time has certainly demonstrated the correctness of that decision. For, during the past 4 years, interest in this topic has increased throughout the world, particularly regarding high-incidence performance and the phenomenon of vortex bursting.

For Sweden such a collaborative activity is of great importance because it provides a means by which a neutral country can avoid the danger of being cut off from the aerospace research activity in the NATO countries. Sweden needs this contact to ensure the viability of its highly successful aircraft manufacturing industry.

From Drougge's original concept, comprising only the National Aerospace Laboratory NLR (The Netherlands), SAAB-Scania (Sweden), and FFA, the project grew to include the German Aerospace Research Establishment (DFVLR), the two German aircraft manufacturers Messerschmitt-Bölkow-Blohm (MBB) and Dornier, the US Air Force (AFWAL), and the Technical Universities of Braunschweig (TU-Braunschweig, West Germany) and Delft (The Netherlands).

Representatives from the four countries selected the generic model geometry, Figure 1, for wind tunnel testing and computational fluid dynamics (CFD) analysis. What eventually evolved was the design of a 65° cropped delta wing with interchangeable sharp, round, and

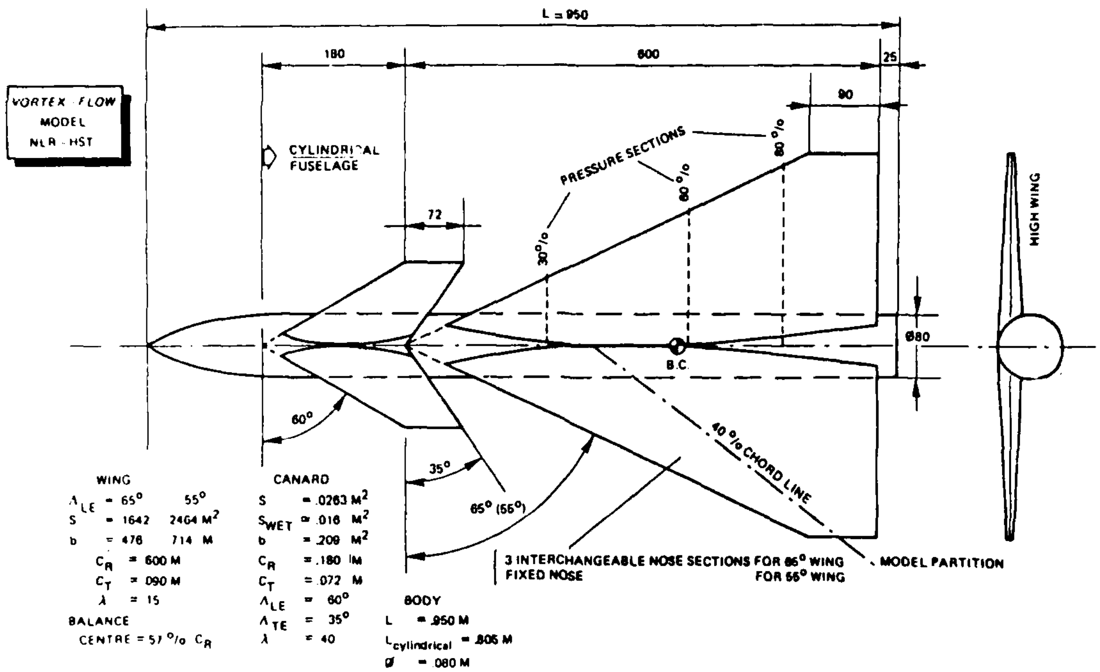

Figure 1. AFWAL vortex wing model.

drooped *leading edges* which could be tested with or without a forward-mounted canard. The model, which had a root chord of 0.600 m, was manufactured by AFWAL. Two smaller models, one a 70 percent scale model of the AFWAL design manufactured by MBB and a 55 percent swept wing manufactured by FFA were also tested. Testing was carried out at FFA, NLR, DFVLR, and the Technical University of Delft. Measured data covered a range of Mach numbers from 0 to 3.9, angles of attack from 0 to 25°, and a range of Reynolds numbers generally between 2 to 9×10^6 (with the water-tunnel Reynolds number being approximately two orders of magnitude smaller). Data includes forces, surface pressures, laser Doppler anemometry (LDA) and 5-hole probe surveys, oil flow, smoke (light sheet), and dye visualization. Computational fluid dynamics (CFD) calculations involving the solution of the Euler equations were contributed by AFWAL, Dornier, MBB, and the Technical University of Braunschweig. An additional feature of the collaboration was that the Euler code developed at FFA by A. Rizzi was distributed to all participants. Figure 2 is a schematic representation showing the experimental and computational contributions of the participants.

First, a broad overview of the symposium will be given. This will be followed by a detailed discussion of some selected features of the flow.

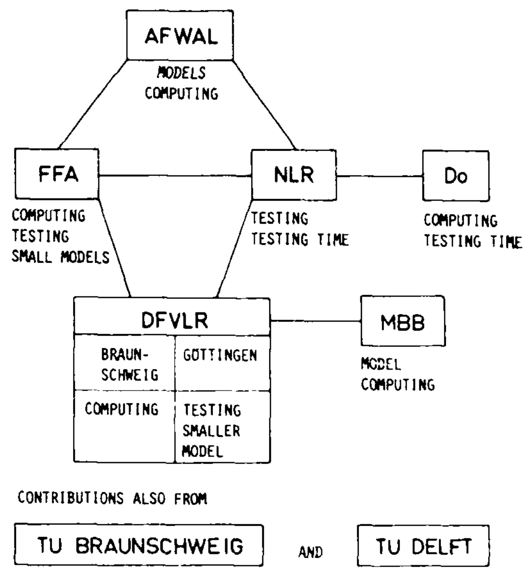

Figure 2. Schematic of collaboration.

Overview of Experiments

In general, the experimental results presented at the meeting showed the expected features of the leading edge vortex flow phenomena. Some additional new features were found. Shock-induced separation for the round leading edge geometry was suggested by the NLR investigators, as was the appearance of a transonic-like normal shock above the wing at M=0.85, α=25°. Some rather abrupt changes in velocity vector direction, suggestive of embedded shock wave, were reported by the DFVLR LDA data. Results from TU-Braunschweig showed a case where a burst vortex on the canard was relaminarized by the main wing pressure field. Five-hole probe measurements from Delft University indicated existence of embedded shocks and some other detailed structures at M=0.85, α=10°. There was an excellent light-sheet smoke flow video from DFVLR at transonic Mach numbers where the plane of illumination was gradually swept from the wing apex to the trailing edge. (A report of the NLR tests is available as NLR TR 85046L and includes the data on microfiche. The DFVLR tests are described in their reports number IB 222-85A 36 and IB 222-85A 37.)

Overview of Computations

Computations using the Euler equations were reported by DFVLR-Braunschweig (Kumar and Das), AFWAL/FIMM (Sirbaugh), MBB (Sacher), Dornier (Hitzel and Wagner), and FFA (Rizzi, Drougge, Eriksson, and Purcell). The cases selected for comparison with the experiments were for the basic wing, sharp and round leading edges, and M_∞=0.4 (α=10°), M_∞=0.85 (α=10°, 20°) and M_∞=1.2 (α=10°). However, calculations were reported for other angles of attack and including also the body and canard. All reported calculations used pseudounsteady, cell-centered finite volume methods. Quite different meshes were used by each group, with mesh densities ranging from 40,000 to 1,000,000 cells. In general the computed results showed good agreement with overall force data (C_L, C_D, C_M) and the general features of the flow. Detailed agreement with surface pressure data ranged from poor to fair. There was considerable difference between each of the codes in this respect. Virtually all CFD investigators predicted vortex breakdown at M=0.85 between α=20 and 25° in agreement with experiments. Many other interesting details were revealed by the computations.

Additional contributions were made by several investigators. Hirschel (MBB) and Rizzi (FFA) presented a kinematic explanation of vorticity generation by Euler equations. A three-dimensional incompressible boundary layer calculation was given by de Bruin and Hoeijmakers (NLR). Das (DFVLR) presented an explanation of vortex breakdown based on the changes in shape of the bound vortex lines. Drougge (FFA) analyzed the drag-reducing effects of leading edge droop at M=1.2 (attached flow) from Euler equation calculations. Müller (FFA) presented some preliminary laminar Navier-Stokes calculations for the round leading edge geometry. Elmeland and Arlinger (SAAB) presented an excellent summary of comparisons with theory and experiments. Questions addressed were:

- The correctness of modeling round leading edge separation with the Euler equations
- Effects of grids and need for embedded grids
- Reynolds number effects and influence of secondary separation
- The importance of vortex breakdown
- The requirements for including canards.

Viscous Effects

The experimental data showed that the effects of the Reynolds number on the forces and moments is virtually negligible for subsonic flow; however, this is not the case in supersonic flow. In addition, far as the pressure distribution on the wing is concerned, a significant Reynolds number effect is seen in both subsonic and supersonic flow. A source of controversy was the extent to which laminar flow appeared on the wing. Since many of the tests were conducted at moderate Reynolds numbers, this was obviously a concern. From a computational point of view it is desirable that a majority of the flow be turbulent in order to reduce the viscous effects which are excluded from the computations. In some cases the boundary layer was tripped in an attempt to assure that the majority of the flow was turbulent. It was difficult, however, to assess the effectiveness of such measures.

As far as the calculations were concerned there was only one successful attempt at including the effects of viscosity. This was the laminar Navier-Stokes calculation of B. Müller of the FFA. His results seem to show that the effect of increasing Reynolds number is to move the center of the primary vortex core closer to the leading edge of the wing and to reduce the level of the pressure peaks. In addition, his calculations picked up the presence of the secondary vortex, which, of course, is missing from the Euler flow calculations.

Figure 3 shows a typical comparison between the Euler predictions and experiments. Here the local pressure coefficient is plotted as a function of percent span at a station located at 80 percent of the root chord. These results are taken from Sirbaugh's presentation (AFWAL/FIMM). As in many calculations, good agreement on the pressure side of the

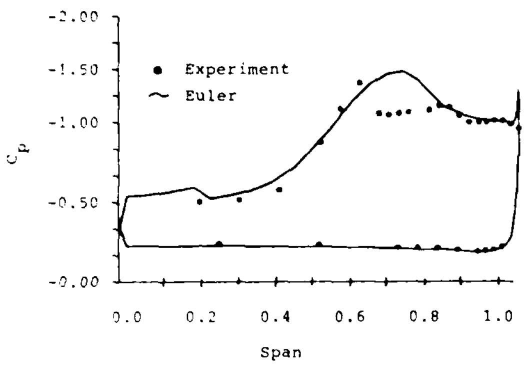

Figure 3. Pressure coefficients in AFWAL wing at Mach 0.85 and 18° incidence.

wing is obtained; however, on the suction surface only a single suction peak is predicted whereas in the experiments a second peak appears due to the presence of the secondary vortex. The inability of the Euler calculations to account for the presence of the secondary vortex has long been recognized as an unavoidable deficiency of the Euler calculations. This is because the secondary vortex is the result of boundary layer separation of the cross flow. Being an inviscid calculation, the Euler calculations are, of course, incapable of picking up this effect. Slightly better agreement is shown for larger angles-of-attack and at stations located farther outboard on the wing.

Round Leading Edge

Drougge pointed out that with a round leading edge, particularly with a drooped, round leading edge, improved off-design performance can be obtained. The effect of the rounded leading edge produces some difficulties in the calculations, however, since it introduces an uncertainty in the location of the line of primary separation. In practice it is found that the location of the separation point of any cordwise location depends strongly on the mesh spacing and the treatment of the boundary conditions on the wing and may, in fact, disappear completely if the mesh spacing is fine enough. In the case of the sharp leading edge this problem does not arise since the primary vortex originates at the leading edge.

Vortex Characteristics

In the Euler calculations, losses in total pressure ranging from 50 to 60 percent are routinely predicted in the core of the primary vortex. Such losses in total pressure require an explanation since the Euler equations do not contain the effects of viscosity which ordinarily are the cause of these losses. Based on a suggestion by M. Landahl, Murman concluded that this apparent anomaly can be resolved by considering the kinematics of the flow in the vortex. He was able to show by means of a relatively simple analysis (Murman and Rizzi, 1986) that the level of the total pressure loss is insensitive to computational parameters such as mesh topology, artificial viscosity, and variations in the initial conditions. This confirms such independence shown by the computations carried out by a number of investigators.

Canard Effect

The effect of a canard mounted upstream of the wing was investigated. Its effect as shown by D. Hummel (TU-Braunschweig) was to move the point of apparent origin of the secondary separation line from the apex to a point midway between the apex and the wing tip. In general, the effect of the canard and its supporting body was stronger in supersonic flow than in subsonic flow. In addition, the presence of the canard raises the angle-of-attack at which vortex bursting on the main wing takes place and results in a loss of lift on the forward part of the wing. The aft motion of the apparent origin of the line of secondary separation also means that the effect of the canard is to increase the nonconical nature of the flow. In addition, in water tunnel tests Hummel observed a reconstitution by the wing of a burst canard primary vortex. This restabilization process experienced by the canard primary vortex has until now only been observed in internal (tube) flows and not in external flows. Hummel also found that, with increasing angle-of-attack and increasing Mach number, the line of secondary separation pivoted toward the plane of symmetry of the wing. The effect of the canard is also to force the apparent center of the primary vortex outboard on the wing.

Murman also developed a criterion for vortex bursting based on the total pressure loss which agreed quite well with experiment. With regard to the bursting process itself, B. Wagner of Dornier (Friedrichshafen, West Germany) showed that no additional pressure loss was associated with the bursting process. This substantiates the widely held view that bursting is basically an inviscid process.

Miscellaneous Computational Features

Calculations of the flow field under apparently identical conditions by different Euler codes appeared to give different results. This was especially apparent in the position of the primary vortex core. A. Rizzi (FFA) predicted that the primary vortex would lie far more outboard (by 10 percent of the cord) than other Euler calculations. Clearly, there is need to address the differences which are being observed between various Euler calculations.

Convergence probably needs to be looked at more carefully. The experience of P. Sacher (MBB, Munich) was that even after several thousand iterations (amounting to more than 25 hours on an IBM 3090) the local pressure coefficients on the wing surface were still changing significantly, particularly in the tip region. Sacher went on to say that it is extremely important to look at the wing pressure distribution to judge convergence since it is not uncommon for the global parameters of the flow such as lift coefficient to converge rather early. If the calculations are stopped prematurely, the local wing loads needed for the structural design of the wing, for example, will be improperly determined.

No solutions were able to show grid independence. Calculations were run with a few as 30,000 and as many 1,000,000 grid points without ever reaching a mesh-independent solution. The tendency with successive grid refinements is to produce higher and higher pressure peaks at the wing tip and to predict primary vortex centers which lie progressively farther outboard.

Future Work

The calculations presented at the symposium showed the Euler solutions are capable of capturing the main features of the flow, including the approximate location and strength of the primary vortex, and in addition are capable of predicting the wing forces and moments with good accuracy. However, to an extent not fully appreciated when this project was undertaken, viscous flow effects play an important role in establishing the static pressure distribution on the wing. In the long term, the dominant role played by the secondary vortex will demand that Navier-Stokes calculations will be required. This will not be an easy task because such calculations will call for careful grid refinement not only in the region near the wing but also in the vicinity of the vortices found in the off-body flow field. Almost certainly this will require some type of adaptive mesh refinement procedure. In addition, the turbulence model will have to cope with highly three-dimensional separated flow. At present there are no turbulence models which will handle these conditions.

As far as experiments are concerned, Hornung (DFVLR, Göttingen) reported that DFVLR plans to do three-dimensional LDV studies on both the AFWAL and the FFA wings. In addition, NASA plans to extend the data base into the 400×10^6 range with experiments in Langley's cryogenic, transonic (NTF) wind tunnel. Further collaborative activity among the partners in this project was discussed in a closed session at the end of the symposium. It is anticipated that these discussions will result in future collaborative activities but perhaps on a much more informal level than have existed up to this point. A report on future activities will be made at the next symposium, which is tentatively scheduled for the spring of 1988 and will be held at DFVLR in Göttingen.

Reference

Murman, E.M., A. Rizzi, "Applications of Euler Equations to Sharp Edge Delta Wings with Leading Edge Vortices," *Proceedings of AGARD Symposium on Application of Computational Fluid Dynamics in Aeronautics*, (Aix-en-Provence, April 1986).

10/21/86

Physics

PREFATORY NOTE TO THE ARTICLES ON STM '86

The awarding of the Nobel Prize to a relatively new discovery is unusual, but as Professor Colton and Dr. Quate state in their article that follows, scanning tunneling microscopy (STM) is "A revolution in the making!" Marking on the manuscript, the editor asked on 10 October, "Is this true?" I was able to write on 18 October, "Yes, STM has been recognized in the 1986 Nobel Prize for Physics." Proof enough!

A timely report is necessary of the significant results presented at the STM '86 meeting held in July at the University of Santiago Compostela, Spain. *ESN* is fortunate that two articles, the second by Dr. Mansour, were submitted by guest authors who have given different thrusts to their reports. These summaries, together with Professor Quate's excellent review article in the August issue of *Physics Today*, should give the reader an idea of how rapidly the application of STM is expanding and how it will impact other sciences and many areas of technology. The proceedings of STM '86, which will appear in a special issue of *Surface Science*, should be a best seller.

David L. Venezky
10/22/86

SCANNING TUNNELING MICROSCOPY--STM '86

STM '86 was the first international conference on STM. It was hosted by the Universities Autonoma de Madrid and Santiago de Compostela, in Santiago de Compostela, Spain, from 14 through 18 July. The conference was organized by Professor N. Garcia (Universidad Autonoma de Madrid Spain), Dr. Jaklevic (Ford Motor Company, US) and Dr. H. Rohrer (IBM Zurich Research Laboratory, Switzerland). Among the 13 sponsoring and supporting organizations was the Office of Naval Research.

STM '86 was preceded by two STM workshops (invitation only): the first was in 1984 in Cancun, Mexico, with only nine participants and nine papers presented; the second was in 1985 in Oberlech, Austria, with 45 participants and 35 papers presented. STM '86, on the other hand, was a much larger conference, open to the general scientific community. Approximately 160 scientists from 17 countries attended a program featuring 71 papers. Approximately 30 percent of the speakers were from each of Switzerland and the US, 10 percent from Spain, 7 percent from Japan, with the remaining speakers from Argentina, Canada, West Germany, Finland, France, India, Mexico, Sweden, the Netherlands, the UK, and the USSR.

The conference was devoted to scanning tunneling microscopy (STM) and its applications to topography and atomic surface structure, surface chemistry, lithography and surface modifications, metrology, biology, tribology, and small-geometry devices.

STM '86 A REVOLUTION IN THE MAKING

by C.F. Quate and R. Colton. Dr. Quate is a professor in the Department of Applied Physics and Electrical Engineering at Stanford University. Dr. Colton, of the Chemistry Division of the Naval Research Laboratory, is currently on sabbatical at the California Institute of Technology, Pasadena.

A revolution in the making! Since the discovery and first successful experiments at IBM Zurich in 1982, scanning tunneling microscopy (STM) has developed as a revolutionary and fascinating technique for the study of atomic phenomena at surfaces. (For a recent review, see "Vacuum Tunneling: A New Technique for Microscopy," by C.F. Quate, *Physics Today*, 8 [1986], 26-33.) Prior to this conference, the STM had been used not only for measuring, with atomic resolution, the topography of ordered crystalline surfaces, but also to define many other kinds of surface structure, for example: disordered, biological, technological, nanometer range metrology, island nucleation/growth, etc. This in itself has given the surface science community a new direction. In addition, this conference showed recent electronic structure/spectroscopy and measurements using the STM which have probed the filled and empty 1-electron density of states at surfaces (within ±2 V of the Fermi level).

Introduction

The STM '86 program was arranged such that the morning session opened with a retrospective, or tutorial, lecture on STM and its relation to other disciplines such as electrochemistry, field ion or electron microscopy, and semiconductor devices. The contributed programs proved to be very broad. They produced a number of exciting results which included highlights that *boggle the mind*. For example, new breakthroughs were reported in the following areas:

- Vibrational spectra of single molecules
- Atomic resolution images of interfaces in water
- Electron DOS spectroscopy/mapping with atomic resolution
- Direct measurement of atomic forces
- Biological molecular imaging
- New STM designs--simplicity personified.

Because of the large number of highlights and exciting results, we have had to be selective in this article to conform to a reasonable length.

Review of STM and Its Future

Professor D. Walmsley (University of Ulster, UK) presented the opening lecture on microscopy tunneling and tunneling spectroscopy in the period before the STM. He reviewed early experimental work on tunneling through thin-film metal/metal oxide/metal junctions and the discovery of the inelastic processes by Jaklevic that led to the identification of hydrocarbon contamination layers at the metal/oxide interface. Possible contributions by STM in the areas of the electronic and vibrational spectroscopy of molecules and the electronic and magnetic structure of superconductors were singled out.

One of the three Nobel Laureates for Physics, G. Binnig (IBM Zurich), the driving force behind the STM and the man who with Rohrer (also a 1986 Nobel Laureate for Physics) first introduced vacuum tunneling for the purpose of imaging, gave an overview on "5 years of STM." He discussed the performance of the present-day STM regarding its stability ($\sim 10^{-4}$ Å in UHV); lateral resolution ($\sim$1.4 Å in graphite and $\sim$5 Å in metals); atomic resolution at the solid/vacuum, solid/gas, and solid/liquid interfaces; operation at high (1000 K) or low (4 K) temperatures; and its ability to obtain the electronic structure ("color") of atoms and real-time images of surfaces. The impact of STM on science was also reviewed, and the future impact in the areas of new devices, surface chemistry, biology, vibrational and electronic spectroscopy, and nano-measurement and fabrication was estimated.

Instruments

New STM Instruments. Most of the twenty posters at STM '86 dealt with design and construction of new STM instruments and with the automation of equipment. Instrument design included, for example:

- A simple STM using cylindrical piezoelements glued to a support was modeled after a beetle lying on its back. It was less than 0.5 cc in volume and cost less than $200 to build (K. Besocke, Institute of Nuclear Research, Julich, Switzerland).
- Coarse positioning of the tip was achieved by a piezoelectric walker with feet using vacuum or air gaps, piezostacks, a magnetic walker, or lever arms. Fine positioning and scanning were achieved by a PZT cubic actuator, a tripod actuator, or a crossbar-type fine piezopositioner (K. Kajimura, Tsukuba Research Center, Japan).
- A piezoelectric translator that operates on the principle of inertial sliding of a platform on a highly accelerated support has been developed. The device provides step sizes from a few nanometers to one micron (D. Pohl, IBM Zurich).
- A micropositioning device consists of a single piezoelectric disk used both for macro- and micropositioning. Step motion was achieved by dividing the metal film on one side of the disk into four quadrants and applying sawtooth voltages to the appropriate electrodes (M. Anders, Justus-Liebig-University, West Germany).
- A new STM has the sample mounted in a horizontal position with the tip coming from above. The movement of the sample in the vertical direction is accomplished by a wedge and lever mechanism. Step sizes down to 10 Å can be achieved in the vertical direction (M. Ringger, University of Basel, Switzerland).
- An instrument that is less sensitive to vibrations and temperature variations than their original design uses two piezoelectric push-pull systems to move a tip system towards a fixed sample. The minimum step size is 0.1 micron. Another instrument uses a compact double-leaf spring system driven by two differential screws to provide the coarse displacement of the sample. The maximum displacement is 70 microns (J. Hermsen (University of Nijmegen, The Netherlands).

Automation. In the area of system automation, U. Bapst (IBM Zurich) described an automated control and data acquisition system (hardware and software) for STM centered around an IBM PC AT or XT computer. A graphic subsystem, called "viewplot," allows direct monitoring of the STM data (z-signals up to 1 kHz) and quick hard-copy output. M. Aguilar (UAM-IBM Madrid) has also developed a PC-based system for control and data acquisition of a STM using commercial hardware. The system is built around an IBM PC AT or XT and includes an IBM Data Acquisition and Control Adapter card, an IBM Distribution Panel, an IBM Professional Graphics Adapter and Monitor, and associated electronics. J. Becker (IBM Yorktown) has developed a comprehensive data acquisition and imaging processing system for an IBM PC AT computer. Both two- and three-dimensional images can be displayed with 1000×1000 pixel resolution in real time as line or grey-scale images. The imaging processing software consists of contrast enhancement, convolution filtering, and background subtraction.

E. Stoll (IBM Zurich) described other image processing methods used to restore STM data blurred by limited resolution and hampered by 1/f and white noise. A low-pass Wiener filter, assuming a Gaussian point-spread resolution function for STM data, was used to suppress white noise. To eliminate the 1/f noise, he fitted the STM power spectrum with a 1/f function, and from the amplitude of the fit he designed a Wiener filter to suppress the 1/f noise.

Methodology. C. Quate and D. Smith (Stanford University, California) gave back-to-back lectures on a variety of STM topics including (1) a new tube scanner for the STM instrument, (2) imaging in real time, (3) the atomic force microscope, (4) STM images of impurity atoms embedded in graphite, (5) charge density waves in $TaSe_2$ and $NbSe_2$, (6) molecular imaging of organic molecules in real time, (7) new reconstruction of Si(111) 7×7, (8) a point contact microscopy, (9) phonon spectrum of graphite, and (10) the vibrational spectrum of a single molecule. The advantages of the tube scanner STM is that it is very rigid and can be scanned rapidly up to ∿40 kHz. The higher scan rates provide images in real time and circumvent the problem of 1/f noise associated with operation in air. The atomic force microscope used a STM to measure the motion of a cantilever beam. The force required to move this beam through distances of $\sim 10^{-4}$ Å can be small enough to allow one to measure the force between single atoms. The force microscope is capable of studying the surface of insulators on an atomic scale. Images of gold atoms embedded in graphite demonstrated that the appearance of surfaces in STM images can change drastically as the distance between the tip and sample is varied. They found that a gold atom just below the surface of graphite appeared as a protrusion in charge density when the tip spacing was adjusted to ∿4 Å, but disappeared when the tip spacing is <4 Å. For $NbSe_2$, they observed a rectangular distribution of charge density waves which they attributed to the manifestation of a slipped layer.

Another highlight of the dual talk was the video tape presentation of molecules in motion on a graphite surface. The recorded images were that of molecular bilayer of cadmium arachidate and of sorbic acid molecules. Electronic tunneling through a 54-Å thick bilayer film is still not understood. They have also been able to image other insulating films such as SiO_2 islands by a photo-assisted mechanism when they shine light on the object.

D. Smith reported on the phonon spectrum of graphite and the vibrational spectrum of sorbic acid at 4 K using STM. The graphite lattice vibration was recorded as a peak in the d^2I/dV^2 versus V curve. The vibrational spectrum of sorbic acid, on the other hand, was recorded as peaks in the dI/dV versus V curve. The peaks in the spectrum lined up with those found for sorbic acid using IETS and the strength of the peaks were much larger than those with IETS.

Dr. C. Leavens (NRC Canada) calculated the effect of room temperature lattice vibrations on the atomic scale contour maps obtainable with STM. He found that the difference between the nominal and effective average vacuum gap was proportional to the mean square fluctuation in the local vacuum gap. His results indicate that if the corrugations of interest are less than a few tenths of an angstrom the effect of lattice vibration should be taken into account when interpreting room-temperature STM contour maps, particularly at low voltages.

Dharmadhikari (University of Poona, India) developed a model to measure surface diffusion coefficients of adsorbates on surfaces. The diffusion coefficients are deduced from current fluctuations caused by fluctuations in the adsorbate density. Dr. J. Valdes (INTI Argentina) used a Fast Fourier Transform technique to calculate the power spectrum of signals from a STM. He observed a preponderance of very low frequency components.

G. Walmsley (University of Ulster, UK) measured the topography of Nb and Pb films deposited (E-beam evaporated) on a quartz substrate. At low substrate temperatures the films were rough and formed large crystallites (100-500 Å). At high substrate temperatures the films were smooth and contained smaller crystallites (∿50 Å).

Applications

Metal Surfaces and Metal Interfaces. Professor Van de Walle (University of Nijmegen, The Netherlands) discussed the topographic and electronic properties of flat and stepped Ni (111) surfaces exposed to H_2. He observed large undulations at the corners of the step that he attributed to the redistribution of charge and DOS effects associated with the adsorption of H. He also reported on dI/dV versus V (voltage) spectra and showed what was interpreted to be vibrational excitation of the C-O stretching mode.

E. Ritter (University of Munich, West Germany) reported on the surface reaction of the hexagonal reconstructed phase of Pt(100) exposed to NO, CO, and C_2H_4. The nucleation of the nonreconstructed (1×1) phase depended on the adsorbate and was apparently homogeneous for NO and CO adsorbates. It was heterogeneous for the C_2H_4 adsorbate, which appeared to decompose at surface steps. W. Kaiser (Ford Motor Company) reported on a new STM designed for the study of metals in ultrahigh vacuum (UVH). He described the pros and cons of different feedback modes used to obtain topography and electronic structure information. He also described the spectroscopy and topography of flat and reconstructed Au(111) surfaces.

P. de Andres (Universidad Autonoma de Madrid [UAM]) presented a barrier potential calculation for tunneling electrons at metal/metal interface. The model dealt primarily with the height of the barrier and the effect of the image force. E. Feuchtwang (Pennsylvania State University, University Park) debated the premise that in the spherical tip model the tunneling current is due to a single s-state at the Fermi level. He found, however, that the tunneling current contributed by p- and d-states could be appreciable ($\sim$10 percent) due to s-d degeneracies.

R. Garcia (UAM) calculated the tunneling current through localized surface states of Au(100) and Ni(100) in order to explain experimentally observed oscillatory behavior in dI/dV versus V spectra when the STM tip voltage was located at the band energies of Au(100) and at the gap energies of Ni(100). He concluded that when the applied voltage is set to the band energy of Au(100) the inelastic effects are not important and that the width and shape of the resonances are dominated by the mixing of surface and bulk states. When the applied voltage was located at the gap energy of Ni(100), the main mechanism of electron transport between the tip and substrate is due to inelastic interactions.

A. Baratoff (IBM Zurich) described how the sample electron DOS localized below the center of the tip affected the tunneling conductance and the perceived lateral resolution, and A. Nitzan (Tel-Aviv University, Israel) presented numerical simulations of model tunneling systems based on the solution of the time-dependent Schrodinger equation. His models include a study of quantum diffusion of interacting particles, inelastic electron tunneling as a one-dimensional nonadiabatic tunneling problem, and nonadiabatic tunneling under friction.

The forces acting between the tunneling tip and the sample have been investigated by U. Dueriq and coworkers (IBM Zurich). Duerig used cantilever beams to measure force gradients between tungsten tips and polycrystalline silver surfaces in UHV. The interaction-force maps of the Ag surface correlated directly with the topographic features associated with the structure of grain boundaries.

S. Morita (Tohoku University, Japan) studied the surface of metal oxides in air. He imaged the large columnar structures and the barrier layer of anodized Al, and he observed the formation of large islands (with flat tops) of Pt deposited on TiO_2 catalysts. R. Chicon (University of Murcia, Spain) discussed an algorithm to reconstruct the real sample surface from the "apparent" surface seen by STM. He talked about curvature-dependent tunneling effects associated with spherical tips and problems--such as double tips--associated with tunneling into deep cavities.

Electrochemistry: Fluid/Solid Interfaces. The next series of talks focused on the study of fluid/solid interfaces and on the applications in electrochemistry. The fluids were either air, water, or liquid nitrogen. A. Arvia (University of La Plata, Argentina) gave the opening lecture, which reviewed electrochemistry and electrochemical phenomena. He described the potential of STM to address fundamental questions in the areas of electrocatalysis and corrosion science. The study of fluid/membrane interfaces was also mentioned briefly.

P. Hansma (University of California, Santa Barbara) gave a very stimulating talk on STM studies involving liquid/solid interfaces. He described three new STM instruments--one designed to operate in liquid nitrogen (one is completed that operates at liquid helium temperature) and two to operate in aqueous solutions. One STM has the sample and its holder immersed in the aqueous solution with a glass-covered tip to reduce the exposed area and minimize the parallel conduction currents. This instrument was used to observe atomic resolution on graphite in water. The surface of gold in saline solution was also imaged. The active lifetime of the tip in saline solution was around 1 hour.

Hansma also studied the plating and the nucleation/growth of Au and Ag islands on graphite from their respective electroplating solutions. In order to overcome thermal drift problems related to cooling by evaporation, Hansma used a single-tube scanner STM in which only the tip is immersed in a small bead of solution. This is deposited on the sample through a small capillary tube. This new instrument was used to record, in real time (using a VCR), the corrosion of Al and Fe in saltwater.

L. Vazquez (UAM) studied the electrochemical faceting and activation of Pt electrodes with STM. He observed the formation of clusters and ridges on the electrode surface which were attributed to electrochemical activity.

Graphite. There were several talks dealing with the topography of graphite measured in air and UHV. Dr. Wiesendanger (University of Basel) has studied several graphite surfaces including HOPG and oxidized HOPG in preparation for the study of graphite intercalation compounds. The aim of the intercalation study is to look for changes in superlattice structures of graphite-interplanar spacing, C-C bond lengths, and two-dimensional intercalant phase transitions. In addition, Wiesendanger studied the surface oxidization of HOPG by Cl_2.

N. Garcia (UAM) tackled the problem of explaining the observed giant corrugations of the graphite surface. These vertical corrugations in the electron wavefunctions have been measured by STM as a function of applied voltage at ∿4 Å in some laboratories and up to ∿8 Å in Madrid. The results from the scattering indicate a corrugation of 0.2 Å and the theory predicts 0.8 Å. Garcia attributed the giant corrugations to elastic deformations induced by atomic forces between the tip and surface.

D. Abraham (University of California, Berkeley) discovered that the apparent graphite corrugation was dependent on the cleanliness of the graphite surface. In air, he found the tunneling current varied only slowly as a function of tip separation from the graphite surface. There was also a large hysteresis, and the measured workfunction was anomalously low. The exponential nature of the I-V curve, as well as the hysteresis, improved markedly when the graphite was placed into vacuum and baked. With the cleanest preparation (cleaning both tip and sample), the graphite corrugation was measured at ∿1 Å and the workfunction approached the expected 5 eV.

J. Pethica (Cavendish Laboratory, UK) commented on another model that would give rise to large corrugation and abnormal workfunction values. He proposed that the tip was contacting the surface and causing the top graphite layer to shear and move along the second layer.

Other papers on graphite included one by I. Batra (IBM Zurich) on the electronic structure calculation of graphite. In addition to the large corrugations, he was interested in the loss of trigonal symmetry and methods that could be used to identify the position of carbon atoms. He concluded that if STM could measure the total local charge density instead of the local density of states at the Fermi level one could distinguish between the A, B, and H sites on graphite. He also concluded that although STM could not see the second layer of graphite, it could "feel" it. He suggested that the loss of trigonal symmetry was caused by the slipping of the top layer of graphite relative to subsurface layers. Dr. Salemink (IBM Zurich) also studied the loss of trigonal symmetry on graphite. He observed a number of topographical defects on the surface of graphite including: (1) domain boundaries between ordered zones, (2) amorphous regions, and (3) dislocations along a high-symmetry direction.

<u>Organic and Biological Molecules.</u> The next series of talks dealt with the analysis of organic or biological molecules. J. Coombs (Cavendish Laboratory) presented the STM images from three types of Langmuir-Blodgett (L-B) insulating films deposited on gold: proto-porphyrin, diacetylene, and triacontaoic acid. Apparent monomolecular steps and terraces were observed. but the measured step heights were not the values expected. The origin of contrast in STM of L-B films was also discussed. Tunneling through the film requires the film to have a low barrier height. In this case, contrast due to changes in film thickness or barrier height (workfunction) would be possible. Tunneling into the L-B film requires the presence of molecular levels or surface states.

J. Gimzewski (IBM Zurich) used STM to image individual molecules of copper phthalocyanine adsorbed on polycrystalline silver surfaces in UHV. He was only able to obtain a stable image for positive tip voltages and for molecules adsorbed at atomically rough sites (at steps). A. Stemmer (University of Basel) used STM and STEM to study vesicles reconstituted from *E. coli* outer membrane porin and phospholipids adsorbed on amorphous carbon films. STM images taken in air showed curved steps which were ∿45 Å in height (and believed to correspond to a single phospholipid layer). G. Travaglini (IBM Zurich) used STM to image large filaments of DNA on graphite surfaces. His best results were with freeze-dried filaments shadowed with Pt or C. He plans to convert his instrument so that it will be suitable for work in aqueous media.

<u>Lithography and Micromaching.</u> Two papers were presented in the area of lithography and micromachining. M. McCord (Stanford University, California) evaluated the potential of STM as a submicron lithographic tool. By operating the STM in a field emission mode, he was able to write a 750-Å line in resist using a beam voltage of 10 V. This linewidth is about 10 times the expected linewidth. The line broadening was attributed to the generation of secondary and reflected electrons which are accelerated back in to the target by the intense fields surrounding the tip. These reflected electrons expose the resist hundreds of angstroms away from the primary beam.

G. Ben Assayag (CNRS-LMM Bagneux) used STM technology to develop a semiconductor micromachining device that has a low ion beam energy (1 kV). He was able to increase the current density of a liquid metal ion source by at least 10^3 times over that achieved by conventional sources. He had positioned the tip of the source to within 10 microns of the target. The source is free of the aberrations caused by optical systems that limit the resolution. It is capable of drilling holes or writing dots or lines of Au or Ga on GaAs with a separation of 0.3 microns.

Semiconductors (Silicon). The last session of STM '86 dealt with the study of semiconductors. The session was opened by N. Lipari (IBM Yorktown Heights) with a lecture on semiconductor technology--the next 5 years. He identified a number of critical technological areas--dry processing, metallurgy, packaging, epitaxy, and process-induced defects--that could potentially use STM in combination with other techniques to solve complex materials, processing, and device problems.

R. Feenstra (IBM Yorktown Heights) gave an excellent presentation on everything and anything you might want to know about the electronic structure of the Si(111) 2×1 surface. He observed the 2×1 surface unit cell which contained a single maxima in the topography, with corrugation amplitudes, at low voltage, of about 0.6 Å and 0.3 Å in the long and short directions of the unit cell, respectively. He was able to determine which surface reconstruction model--buckled versus pi-bonded chain--best fit the data by comparing STM data with the DOS obtained from photoemission and inverse photoemission studies, and by studying the effect of polarity reversal on the STM corrugation. The long corrugation was not affected by a polarity reversal, whereas the short corrugation was shifted by 180° when the polarity was reversed. The sign reversal demonstrates that the short corrugation arises from a purely electronic state. The results were interpreted in terms of the pi-bonded chain model.

R. Koch (IBM Yorktown Heights) has monitored the growth of a 0.5 monolayer of SiO_x on Si(100) 2×1 and Si(111) 7×7 exposed to O_2. SiO_x regions appeared as potholes on the surface which become flat again when an electron jumps into the trap. By fixing the tip over the top of the trap and by varying the tip voltage, the electron trap can be turned on and off, allowing one to characterize its switching noise and I-V characteristic. In the future Koch plans to look for changes in lattice parameters due to electron capture.

R. Hamers (IBM Yorktown Heights) described a new method to study the electronic structure of surfaces *simultaneously* with their topography. On Si(111) 7×7, he was able to identify surface states due to dangling bonds on the 12 adatoms, states localized on the atoms in the layer beneath the adatoms, a state due to Si-Si backbonds, and a state localized at the deep corner hole of the Si(111) 7×7 surface. On Si(001), states were observed that correspond to the Si-Si dimer as well as the dangling bonds at the edges of the dimer.

Several papers dealt with the study of compound semiconductors or semiconductor interfaces. A. Humbert (U.A. CNRS, Marseille) examined the STM corrugation patterns associated with GaSe. He found the corrugation to vary with tip voltage--smaller corrugation for higher voltages. The dI/dV versus V data revealed a surface state associated with Ga present in the second layer of the compound semiconductor.

P. Muralt (Free University of Berlin, West Germany) used STM to characterize the semiconductor pn junctions of a GaAs diode and $Al_xGa_{1-5}As$/GaAs laser diode. The STM allowed him to spatially resolve the voltage drop across the semiconductor interfaces and to map out zones of space charge near the interface. Space charge regions between 200 to 500 Å were observed.

H. van Kempen (University of Nijmegen) developed a photoconductive STM method in which semi-insulating materials, such as GaAs, are illuminated by a light source where $E_{wavelength}>E_{gap}$. Photo-excitation of electron-hole pairs across the band gap creates a conductive surface that is suitable for imaging with the STM.

Concluding Remarks

H. Rohrer (1986 Nobel Laureate for Physics, IBM Zurich) ended the conference with a brief review of the history of the STM meetings. He plotted a curve showing the evolution of STM from an early emphasis on instrumentation to the present-day emphasis on methods development and finally to the future of applications and problem solving. The figure caption reads: "Can I See It? - I See It. What Is It? - It Is!"

The conference ended with thanks given to the hosts and organizers for a very stimulating and exciting program, for the beauty and warmth of Santiago de Compostela and its people, and to the several enjoyable social events highlighted by the trip to Romeria and the conference banquet.

STM '87 will be held in California in July-August 1987.

10/10/86

STM '86 HIGHLIGHTS OF RESEARCH FROM SIX EUROPEAN LABORATORIES

by Azzam N. Mansour. Dr. Mansour is in the Surface Evaluation Faculty of the Naval Surface Weapons Center, Silver Spring, Maryland.

This article presents my impressions about current European research in scanning tunneling microscopy, which were formed while attending this conference. My intent is to highlight certain research projects and trends, and not to provide a detailed account of each technical presentation. The choice of topics was, of course, influenced by my own background and research interests. Before proceeding with this program, it seems appropriate to give a brief summary of STM.

The discovery of the scanning tunneling microscope in 1982 by Binnig and coworkers (Binnig et al., 1982, 1983) is one of the truly fundamental developments in surface science in the recent past. This microscope offers, for the first time, the capability of directly imaging individual atoms as well as their empty and occupied local charge densities of states in real space. The principle of operation of the microscope involves the strong distance-dependence of the tunneling current between two closely spaced electrodes. For two parallel electrodes with a vacuum gap, the tunneling current, J_t, is proportional to $(V_t/S)\exp(-A*W^{\frac{1}{2}}*S)$ where A is approximately equal to $1.025(\mathrm{eV})^{-\frac{1}{2}}(\text{Å})^{-1}$, W is the average of the two electrode work functions, S is the distance between the electrodes, and V_t is the applied voltage between the electrodes. For appropriate values of W (say 5), the tunneling current changes by an order of magnitude for a change of 1 Å in S (say, from 10 to 9). Therefore, if a sharp tip is brought sufficiently close to the surface (say 10 Å), and then scanned parallel to the surface in two dimensions (x and y), while its height (z) is adjusted to maintain a constant tunneling current at fixed tip-to-sample voltage, the resulting up-and-down motion (corrugations) forms a contour map of the surface. Furthermore, if the voltage dependence of the tunneling current is measured, a contour map of the local charge density of surface states in real space can be obtained. With this microscope, a vertical resolution of 10^{-4} Å and a lateral resolution of a few Å are often achieved. Although scanning tunneling microscopy has been mainly used to study vacuum/solid interfaces, it can also be used to study gas/solid and liquid/solid interfaces at ambient conditions (Drake et al., 1986).

In Europe, several laboratories have developed STM capabilities. Following is a discussion of the highlights of current STM research in some of these laboratories.

IBM Zurich Research Laboratory, Switzerland

A. Baratoff criticized the Tersoff-Hamann theory of STM (Tersoff-Hamann, 1983, 1985). In this theory, the tip is represented by a single spherical wave function and in the limit of small voltages, the tunneling conductance is found to be proportional to the local density of states of the sample at the center of the tip, which leads to a simple estimate of the lateral resolution of STM. Starting from an expression for the Fourier transform components of the tunneling current derived from the general transfer Hamiltonian formalism, Baratoff showed that the approximation resulting from the Tersoff-Hamann theory leads to an incorrect dependence of the tunneling current on tip radius and, typically, to overestimation of the lateral resolution.

U. Duerig reported on experimental observations of forces acting between the tunnel tip and sample during STM measurements. He presented data for tungsten tips and polycrystalline silver surfaces prepared under ultrahigh vacuum conditions. Positive and relatively large second derivatives of the potential were detected for the whole range of tunnel distances investigated. This range was 6 Å, corresponding to tunnel resistances of 10 to 1000 megohms.

I. Batra reported on an STM study of the (0001) surface of graphite. Over relatively wide areas containing many unit cells, corrugation over several Å are easily discernible. Using self-consistent electronic structure calculations, one finds a 0.8-Å corrugation of the density of states at the Fermi energy and, hence, the observed corrugations do not arise form the surface charge density at the Fermi energy. The somewhat larger corrugations (approximately, 2 Å) and the lack of trigonal symmetry can be attributed to the slipped geometry of the underlying layer. Batra noted that huge corrugations (larger than 2 Å) are probably due to interatomic forces between tip and sample surface.

H. Salemink reported on an STM investigation of the topography of defects in highly oriented pyrolytic graphite (HOPG). The following defects were observed directly with atomic resolution:

- Domain boundaries with ordered zones
- Local areas with loss of rotational symmetry (amorphous material)
- Dislocations along high symmetry directions.

J. Gimzewski and colleagues used STM to image individual molecules of copper phthalocyanine (semiconducting molecules) adsorbed on polycrystalline silver surfaces. Submonolayer coverages (0.1 to 0.4) of copper phthalocyanine were prepared by sublimation in ultrahigh vacuum. The authors observed molecules on stable adsorption sites at atomically rough regions. They also found evidence for surface diffusion during scanning over molecules adsorbed on flat areas of the sample.

Universität Basel, Switzerland

R. Wiesendanger and colleagues have applied STM to the study of positional and chemical short-range order in disordered systems like $Rh_{25}Zr_{75}$ metallic glasses. The authors observed: (1) extremely flat surfaces with a root-mean-square roughness of 1 Å after argon ion sputtering (independent of the argon ions' energy), (2) the presence of nanocrystallites in the amorphous matrix, and (3) that surface modification results if the sample is exposed to 1 microampere of current and then scanned with one nanoampere of current.

R. Wiesendanger and colleagues have also applied STM to study the topography of various graphite surfaces. They have investigated the surface structure of highly oriented pyrolytic graphite (HOPG) and of HOPG oxidized in Cl_2 gas at 700 K. For the freshly cleaved surfaces they observed: (1) flat regions of the order of 50 Å with hexagonal symmetry, (2) defect lines intersecting each other at different angles, (3) surface steps, and (4) point defects or adsorption sites. The oxidized surface exhibits deep terraces with a surface topography that is noticeably different from that of a freshly cleaved surface.

A. Stemer and colleagues have applied STM to the study of biological membranes. They have studied vesicles reconstituted from *E. coli* outer membrane porin and phospholipids. Images taken by the STM operated in air showed curved steps of approximately 45 Å in height. Shape and step height suggest that the observed structures may represent the edges of porin vesicles adsorbed on carbon films.

A. Brunner and colleagues have applied STM, x-ray photoelectron spectroscopy, and ultraviolet photoelectron spectroscopy to examine the surface topography and composition of a thin film of Pd_2Si on an Si (100) substrate after various sample treatments. The following characteristic features were observed: (1) islands with different structures for the air-exposed untreated surface, (2) microcrystalline grains for polycrystalline Pd_2Si after sputtering, (3) formation of islands at the interface between Pd_2Si and Si, (4) hillock-like structure for the Si substrate, and (5) structural relaxation within minutes after field desorption.

Universidad Autonoma de Madrid, Spain

P. Andres reported a theoretical calculation for the interface potential and the mean barrier height for electrons tunneling in a tungsten-gold configuration, with variable distance between the electrodes.

L. Vazquez and colleagues applied STM to investigate the microtopography of electrochemically treated platinum surfaces. The STM images indicated that: (1) the untreated surface is very rough on a scale of 100 Å, (2) the surfaces treated by electrochemical faceting show regions with smooth surfaces and regions with localized clusters approximately 400 Å in size, and (3) the surfaces treated by electrochemical activation show pebblelike structure of the order 200 of Å.

A. Baro and colleagues reported on the effect of interatomic forces in STM (Solar et al., 1986). They showed that STM images can be dominated by elastic deformations due to the presence of atomic forces between tip and sample. STM images of the graphite (001) surface taken at constant voltage with varying tunneling current showed huge corrugations (up to 8 Å), interpreted by Baro et al. as resulting from interatomic forces acting between the tip and the graphite surface.

University of Nijmegen, The Netherlands

G. van de Walle and colleagues applied STM to investigate the topographic and electronic properties of both the (111) flat surface and atomic steps of nickel. Micrographs of the (111) plan show a hexagonal pattern with a dimension of two times the unit structure and a corrugation of 1 Å. The corrugation amplitudes increase (reaching up to 2 Å) at corners of steps. Various peaks in the density of states were observed at energies approximately 1 eV above the Fermi energy.

Van de Walle also applied STM to the study of intrinsic semi-insulating materials such as GaAs. In the reported experiment, the sample was illuminated by a He-Ne laser and by incandescent light to produce a conductive surface layer. This procedure demonstrated the possibility of applying STM to intrinsic semi-insulating materials in a mode referred to by the authors as "photoconductive STM."

Universität Munchen, West Germany

E. Ritter reported the results of an STM study on the local mechanism of adsorption on the hexagonal reconstructed phase of Pt (100). The nucleation of the Pt (1X1) phase from the hexagonal reconstructed phase of Pt (100) depends on the adsorbate and is apparently homogeneous for adsorbed NO and CO. No such nucleation of the Pt (1X) phase was observed for adsorbed C_2H_4.

Cavendish Laboratory, UK

J. Coombs reported the results of an STM study of Langmuir-Blodgett insulating films deposited on gold. Three films were studied: proto-porphyrin, diacetylene, and trichenosoic acid. Monomolecular steps and terrace areas with more than one layer were observed. For protoporphyrin$_6$ regular and irregular features 20 to 30 Å in size, were observed. These might represent individual molecules.

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10/10/86

AN ALL-EUROPEAN CONFERENCE ON ATOMIC SPECTROSCOPY

by Paul Roman. Dr. Roman is the Liaison Scientist for Physics in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on assignment until September 1987.

The 18th conference of the European Group for Atomic Spectroscopy (EGAS, a unit of the European Physical Society) was a high-spirited, commendably organized, and intensively interactive meeting that took place at Marburg, West Germany, from 8 through 11 July. Apart from Europhysics funds, substantial financial support was provided by the West German research organization, DFG, and the Ministry of Science and Arts of the State of Hessen; twelve German industrial concerns contributed as well. The facilities for the meetings were generously supplied by the administration of the ancient Philipps University of Marburg.

It may be interesting to observe that the last EGAS meeting (in 1985) was submerged into a giant biennial meeting called ECAMP (European Conference on Atomic and Molecular Physics), which took place in the somewhat distracting atmosphere of Amsterdam (see ONRL report C-4-85 or *ESN* 39-9:438-441). In my opinion, there were both advantages and disadvantages in holding a "group meeting" instead of a "grand conference." On the positive side, I mention the intimacy and close working contacts as well as, surprisingly, the much broader representation of nations. On the negative side, a lack of focus and a tendency toward minor technical details was clearly visible.

There were 280 participants--an ideal number for a broad topic. The distribution among nationalities was most unusual. The majority, 94, were, of course, from West Germany. But the next largest contingent--59 physicists--came from Poland, of all places (and I am told that 10 more applied but were not given exit permits from Poland). I am aware of the relative health and good traditions of Polish atomic physics, but surely there must have been something more (probably political considerations) determining this dominance. Consider: there were only 36 French, 16 Dutch, 15 Swedish, 15 British participants, and a small contingent from 13 additional countries. From overseas, I identified only two US, one Canadian and one Australian.

The program committee decided to cover every and all areas of atomic spectroscopy, defined in a broad sense. In addition, a successful attempt was made to go beyond the strict conventional limits of the field and to include topics where applications of atomic spectroscopy may play an important role. The result of these policies gave rise to a welcome breadth of structure but also to an eclectic one which prevented the organizers from achieving well-delineated sessions. There was only a continuous stream of contributions, not necessarily successive in any causal relationship. Being somewhat of an outsider, I did not find rational groupings of contributions to allow for a structured reporting. Therefore, the best I can do is to split my survey of selected talks into two groups: invited papers and contributed talks.

There were 20 invited papers and 31 contributed talks--counting also the lectures that were given at a 1-day excursion to the Darmstadt heavy ion accelerator facility (see below). The invited papers were 50 minutes long; the contributed talks lasted 15 minutes. Strong chairmen managed to keep time open for adequate discussions. There was also an alarmingly high number (155) of poster presentations. Fortunately, they were nailed on the boards during three separate late-afternoon periods and thus, did not interfere with the orally presented papers.

An interesting innovation was the arrangement for a full-day's visit to the Federal German national institute for heavy ion research (Gesellschaft für Schwerionen Forschung, GSI) at Darmstadt (1½ hours' bus drive). Apart from the lab visits, there were a number of fine invited talks; some of them I report in the third section of this article.

I have not only a detailed program and a list of participants (with addresses), but also a 400-page, magnificently produced booklet containing detailed abstracts of all contributions (including ones for the posters). Upon request, I will be glad to send copies for personal use to colleagues. However, the publishers (European Physical Society) request that these summaries be not quoted in the literature as published results, and that, specifically, numerical data contained in the summaries be not quoted in any context except with the permission of the authors.

Invited Papers

The keynote address of the entire meeting, a paper by G. Wunner (University of Tübingen, West Germany), illustrated well the organizers' goal of combining atomic spectroscopy with whatever distant fields in which it might have a stimulating role. Wunner, in a brilliant presentation, reported on theoretical work related to atoms in superstrong magnetic fields--that is, in fields up to the strength of 10^{10} Tesla. Clearly, such fields cannot be seen or produced in our laboratories and are present only in very special (though not too rare) celestial systems: compact cosmic objects such as white dwarts and, more specifically, neutron stars/pulsars. Wunner and his colleagues devised computation methods (different in important aspects from similar techniques now known) that permit a very accurate determination of one-electron-system spectra and wave functions in superstrong magnetic fields. The full Hamiltonian contains the central-symmetric Coulomb part and the axially symmetric magnetic terms and thus, it cannot be separated. But Wunner determined, for cases of special physical content, a cutoff parameter (related to the magnetic field strength) below which the expansion is done in terms of spherical harmonics, and above which, in terms of Landau functions (i.e., a radial wave function multiplied with a Laguerre polynomial). Both systems are complete. Thousands of base functions must be used in each domain. One of the major results of the study was a clear calculation of how, even in low-lying states, the dominating Lorentz forces cause the atoms to squeeze together into an almost linear structure. Furthermore, the calculations of what seem to be hopelessly complicated level splittings, crossings, oscillations in extreme magnetic fields, was circumvented by exploiting the phenomenon of "stationarity" of atomic lines. This means that in the transition region between Coulombic and magnetic dominance, *most* lines become strongly B-dependent and change their positions by several hundred nanometers within a single B-decade, but a few, easily selectable lines run through minima and maxima of the wavelength--i.e., they are much less sensitive to variations of the magnetic field and produce distinct observable features in the inhomogeneous dipole field of the source (a star, in this particular case). One success of the Tübingen theorists was a complete accounting for the spectrum of the white dwarf Grw+70° 8247 which defied explanation for decades. It turned out that the explanation is given by stationary components of Balmer transitions in hydrogen. The calculations also determined that the polar magnetic field strength of the star is 3.5×10^{4} Tesla. Other calculations successfully attacked the study of cyclotron transitions of free electrons in immense magnetic fields--these are relevant for the understanding of x-ray pulsars. Finally, related calculations concerned with highly excited states in moderate (several Tesla) laboratory magnetic fields had spectacular success in explaining the behavior of Rydberg atoms. Furthermore, phenomena which are characteristic of the onset of "quantum stochastic" behavior in certain model Hamiltonian systems, are found also by Wunner's group in the quantal energy spectra of magnetic Rydberg atoms. This opens up the way to study, both by theory and experiment, phenomena that are typical of the quantum properties of so-called "non-integrable" systems. The clue may be found via working on atoms in extreme magnetic fields.

From the extremely strong field to the extremely weak: the next invited paper I briefly report on dealt with experiments where a single proton in a single cavity-mode of radiation is interacting with a single atom. The energy involved is about 10^{-20} W. Many readers will know that I am referring to the celebrated single-atom-maser (more precisely: Rydberg maser) study of H. Walther's group at Garching (see *ESN* 40-8:287-290.) At Marburg, G. Rempe (Max Planck Institute and Physics Section of the University of Munich, Garching, West Germany) supplied a good overview, emphasizing why the advent of frequency tunable lasers (with which Rydberg states can be easily produced) made the Rydberg maser possible. The reasons are:

1. Highly excited Rydberg states are very strongly coupled to the radiation field.

2. Transitions to neighboring levels are in the region of millimeter waves so that cavities with low order modes can be built easily and ensure long interaction times.

3. Rydberg atoms have long, spontaneous lifetimes so that only the coupling with the selected cavity mode is important.

Rempe recalled some earlier effects that have been already described at other conferences (Menschede and others, *Physical Review Letters*, 54 [1985], 551) then reviewed quite recent experiments which verified the quantum collapses and revivals predicted by theory.

As I noted in the introductory paragraphs, the EGAS meeting had no focus. However, the single hot topic touched by several speakers was cooling and storage of atoms and ions (pun intended). The key talk was given by W. Ertmer (University of Bonn, West Germany). He talked about laser cooling of free atom beams and attempts at storage. The larger part of his presentations was tutorial. In his introduction, he gave three motivations for research on atomic beam cooling: it enables ultrahigh resolution atomic spectroscopy, unusual collision experiments, and traps for neutral atoms. While his illustrations of the basic features of the cooling process were fairly well known, I was struck by his remark that, ultimately, the cooling system implies a total deceleration of 94,000 g! In the second section of his talk, Ertmer reviewed progress at his department in the production of a steady flow of cold atoms with a density of about 10^6 cm^{-3} and a temperature less than 50 mK. In the last part of his address, he discussed progress toward forming a radiative trap by laser beams, such as an arrangement with six orthogonal beams directed toward one point, yielding a confinement time of nearly 0.1 s. Ertmer pointed out that, in this arrangement, the laser beams' action may be said to create "optical molasses," which cools the atoms to the quantum limit of about 240 μK. The last comments were directed toward the goal of constructing not only neutral atom traps but also "cooling rings," and a final remark raised the hope of producing a direct experimental path to achieve Bose condensation by such techniques.

The invited talk presented by C. Cohen-Tannoudji (École Normale Supérieure, Paris, France) was closely related to the topic of Ertmer's presentation. The speaker gave a fascinating physical picture and an intuitive description for the understanding of atomic motion in laser beams. The approach is based on the dressed atom model. Particular applications included radiative cooling and laser trapping. Speculations concerning the possibility of observing quantum jumps on a single trapped ion were also put forward. I thoroughly enjoyed the talk, and my comment is: "Si non è vero, è ben trovato."

Stored atomic ions were also the subject matter of the talk given by G. Werth (University of Mainz, West Germany). He pointed out that the basic features of ion traps has led to experiments which have greatly increased the precision of certain spectroscopic data and introduced new possibilities for the investigation of fundamental properties in atomic physics. Werth told us, however, that after several years of ion trap measurements, a number of properties, especially of larger ion clouds, are still not completely understood. Examples of such ill-understood effects include the question of the average kinetic energy of an ion cloud at different parameter-points of the trap, space charge effects, and observed strong oscillations in the fluorescence intensity from laser-excited ion clouds.

It was inevitable, of course, to also have a major talk on optical bistability. It was presented by one of the leading optical scientists in Spain, E. Bernabeu (Universidad Complutense, Madrid). He gave a largely tutorial talk on the subject, very cleverly presenting it from a spectroscopist's point of view. He analyzed light propagation through a nonlinear vapor medium and payed special attention to the role of induced birefringence. He subsequently recapitulated earlier researches in his group (see *ESN* 39-7:335-341), considering the dependence of bistability in a Fabry-Perot cavity on a number of parameters. Finally, he focused on other resonant cavity configurations; in particular, on a double ring device. This arrangement provides additional degrees of freedom for the control of the hysteresis cycles. The obligatory comments on instabilities and chaos concluded the fine talk.

Contributed Papers

Not being an expert in atomic spectroscopy, I felt that most of the contributed papers were highly specialized (or even overspecialized)--hence I briefly report only on a very few which "resonated" with my mind's motion.

M. Inguscio (University of Pisa, Italy) talked about high-resolution tunable laser spectroscopy in the far infrared (FIR). He reminded the audience that FIR spectroscopy has been hampered so far by the lack of a well tunable source, since important transitions in this region come from fine-structure in atoms or molecules and from rotation in lighter molecules. Therefore, the recent development of good metal-insulator-metal (MIM) point-contact diode FIR sources must be considered as a major breakthrough. (These are easily tunable from 0.3 to 6.3 THz by combining on the device laser beams from two different CO_2 lasers.) After discussing technical details for these excellent FIR sources, Inguscio summarized FIR high-resolution applications such as measurements in excited molecular states, measurements of pressure broadening and shifts, and demonstration of sub-Doppler resolution. (Some of the experiments were done in collaboration with scientists from the Boulder, Colorado laboratory of the National Bureau of Standards.) Finally, the speaker noted further research plans in the following areas: (1) collisional energy transitions, (2) frequency lock of FIR sources (3) extension of research to electronic and ultraviolet spectra.

Doubly excited states near the second ionization limit were the special concern of a French research group, the Laboratory Aimé Cotton of the CNRS, Orsay, France. P. Pillet talked about double Rydberg spectroscopy of the Ba atom. Double Rydberg states have been produced by multiphoton laser excitation. In the analysis, two classes of such states have been considered: two-electron systems ($n\ell n'\ell'$) where $n \sim n'$; and where $n' >> n$. In the first case, the correlation between the electrons becomes predominant. In the second case the outermost electron is moving in the field of the ionic core, partly screened by the inner electron. The speaker called attention to the fact that higher excited double-Rydberg states of the studied Ba atoms have a tendency to autoionize into highly excited Rydberg Ba^+ ions. A new detection method has been developed by using microwave ionization coupled with a double time-of-flight spectrometer.

Another French group, the Hertz Laboratory of Spectroscopy, Paris, reported on an entirely different but, for a one-time elementary-paticle-theorist (such as I), quite exciting topic: Ph. Jacquier talked about a novel experiment intended to measure parity violation in Cs, based on the detection of the excited atoms by stimulated emission. The experiments are in a very preliminary stage. Cs atoms are excited to the 7s state by a powerful pulsed laser operating at 540 nm. The excited state is detected by a transient gain which appears on a probe cw-laser tuned to the $7s$-$6p_{3/2}$ transition (1.47 µm) and collinear with the excitation beam. Doppler broadening is avoided. Hence, the probe laser can be tuned to one particular hyperfine splitting component of the transition, thus allowing detection not only of the polarization of the excited state but also of its alignment. An analysis showed that, eventually, the propagation of the probe through an optically thick vapor will induce an amplification of the parity-violating asymmetry.

One of the most impressive presentations from the Polish delegates was, for me at least, about the research done at the Physics Institute of the Krakow University, read by J. Zachorawski. The topic was observation of degenerate four-wave mixing (with phase conjugation mirroring) in high density (10^{15} atoms/cm^3) Ba vapor, contained in a heat pipe oven equipped with a cylindrical thermionic diode for the detection of atomic excitations. The same experiment also studied self-focusing and self-defocusing effects, and the so-called conical emission phenomenon. All studies were done in the vicinity of the 553.5-nm resonance line of Ba. The light source was a nitrogen-laser-pumped tunable dye laser of 1-kW peak power and spectral width of a few GHz. Two strong, counter-propagating pump beams were used, and a weak probe beam angled at a few degrees.

The Presentations at Darmstadt

As I noted in the introduction, the EGAS meeting transferred its venue for a whole day to the GSI at Darmstadt. GSI is one of the German "Grossforschungseinrichtungen" charged with pioneering work using high energy, highly charged heavy ions for research in atomic physic, nuclear physics, nuclear chemistry, and solid-state physics. The current annual operating budget is DM80m (about $38m), of which 90 percent is from the federal government, and 10 percent from the State of Hessen. GSI employs 535 people and, apart from consortia with numerous West

German universities and institutions, has working interactions with 26 foreign countries. Even the presently run basic machine, a sophisticated linear accelerator called UNILAC, is unique in worldwide respect since it was the first one of its kind capable of accelerating ions up to those of uranium. The present capability of UNILAC is limited by 20 MeV/nucleon.

One of the invited speakers, P.H. Mokler (GSI) reviewed current work done with UNILAC in the area of few-electron ion spectroscopy. He reported on experiments with H- and He-like ions up to atomic numbers of about Z=40, and with F- and Ne-like ions for practically all atomic numbers up to Z=90. He compared the pros and cons of three available approaches: recoil ion light sources, the beam foil excitation method, and the deceleration gas spectroscopy procedure (in combination with a final electron capture). Finally, he indicated plans for the future: the study of Z^{1e} and Z^{2e} spectra with Z equaling about 90. Under these circumstances, higher order quantum-electrodynamical effects will become directly measurable.

Of course, these experiments cannot be done with *UNILAC*, and indeed, two brilliant talks communicated to us the excitement of the institute's development staff. The federal government began releasing funds for an almost incredible enlargement of the GSI facility: a heavy ion synchrotron (SIS, for Schwerionensynchrotron) and an experimental storage-cooler ring (ESR, meaning simply Experimentierspeicherring) will be built and completed, it is expected, by the end of 1989. (See Figure 1 for the layout). Advanced design details and a few prototype elements already exist; the funds allocated for SIS alone amount to DM47.3 million (approximately $21 million).

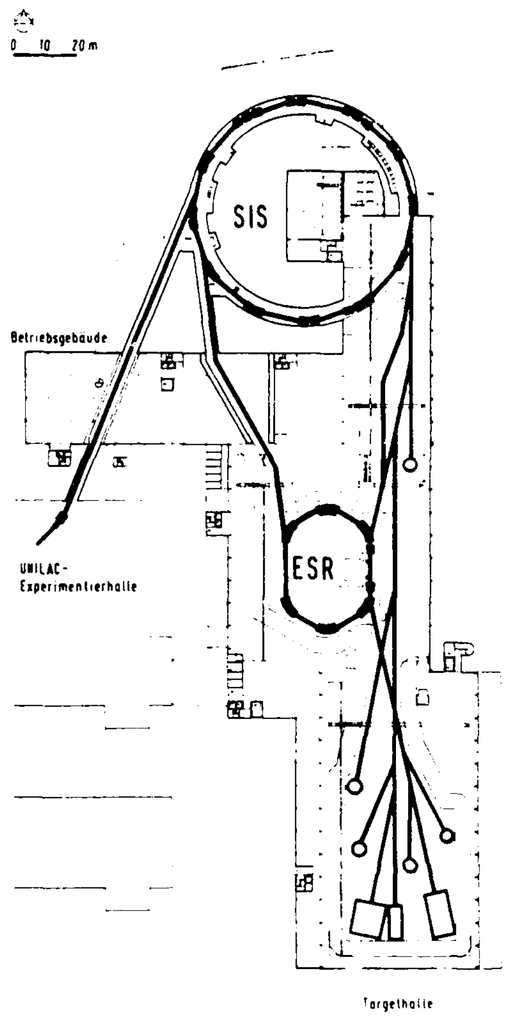

Figure 1. Layout plan of the heavy ion synchrotron SIS and the experimental/ storage ring ESR.

F. Bosch gave an overview of the entire new facility as planned. The SIS will be fed by the existing UNILAC, after suitable modifications on it are done. The stripped high-energy ions from the improved UNILAC will be injected into the 206-m circumference SIS which will have a maximum bending power of 18 Tm. It will accelerate the ions to maximum energies within 10 to 30 turns. The cycling rate (at the highest energies) will be 1 Hz. An example of the SIS performance is that U^{78+} ions will be accelerated easily to a maximum energy of 1 GeV/nucleon. There will be a slow extraction system (for direct experiments) and a fast system which transfers a bunch structure into the ESR during a single turn. (In the course of this transition, a second stripping may be done.) The bending power of the ESR, which has six straight sections (two of them, the experimental areas, being 9.5 m long), will be 10 Tm. The net result will be that, for example, U^{92+} ions can be stored with 556 MeV/nucleon energy, Kr^{36+} with 650, and Ne^{10+} with 834 MeV/nucleon. Alternatively, a reaction target can be installed to obtain Coulomb breakup, fragmentation, or fission of the beam ions. Effective accumulation of radioactive beams will also be possible. Whereas somewhat similar installations are planned or being built in other countries, the GSI facility will be prominent because it will lead to extremely high intensities (ESR will store 10^8 to 10^{11} few-electron [or bare] ions up to uranium) and the momentum spread of the beam is expected to be at least as low as 10^{-5}--hopefully even 10^{-6}. (This would be two orders of magnitude below anything elsewhere.) The achievement of the highest possible phase space densities is indeed the major concern of the designers.

In the second half of his talk Bosch indicated a vast number of physics experiments that one will be able to do with the new facility. The richness of possibilities is so amazing that frankly, I failed to keep track of all ideas listed. But some examples follow. First, in the area of atomic physics: quantum-electrodynamical effects for high-Z atoms (such as Lamb shifts, magnetic moment of bound electrons, binding energies); tests of the unified electro-weak interaction theories (parity violation in atoms, including subtle side effects); more conventional processes (such as study of the quadratic Doppler effect, fine-tuned spectroscopy of Rydberg states, resonant laser excitation of heavy atoms with few electrons, spectra of radioactive isotopes.) Curiosities on other levels will become studyable too, such as beta decay into bound states, investigation of primordial nucleosynthesis in the laboratory, fusion experiments, probably x-ray lasers too...and, who knows, direct production and detailed study of quark-gluon plasmas.

As if this bold planning were not enough, there already exists on paper a project, envisaged to come to fruition within 10 to 15 years; this would consist of adding one or more superconducting collider rings where one would provide center of mass energies over 20 GeV/nucleon for heavy ions up to U^{92+}, with very high luminosities and excellent phase space density.

I already noted that one of the distinguishing features of the currently constructed SIS-ESR system will be a minimalization of the size and of the divergence of the stored beam of particles. This, of course, must be done without appreciable loss of intensity. The appropriate method for achieving the feat is beam cooling--and, in particular, as D. Liesen (GSI) elaborated in his talk, electron cooling. Electron beam cooling for the reduction of the phase space of particles has so far been used only for proton beams. The GSI facility's ESR will use this method, for the first time, to achieve cooling of heavy ion beams. The ion beam will be superposed with a countercirculating monoenergetic electron beam of the same energy and with a small longitudinal and transverse energy spread. The cooling arrangement will be incorporated in one of the long straight sections of the ESR, occupying a 2-m-long part of it. The completed electron circuit will have a 103-m circumference.

I have two brochures from GSI describing current plans for the SIS-ESR system, and will be glad to supply copies on request.

Concluding Comments

This was a fine, well-organized, thoughtfully conducted meeting. Interest and enthusiasm, as well as professional, focused discussions were the hallmarks of the sessions, which were well-attended right up to the last meetings on Friday evening. It may have been the magic of the sleepy old university town, or the somewhat rigid but well-intentioned sequence of social activities, but in any case, old professional contacts were joyfully renewed or turned into friendships, and new contacts were made with unusual ease. Once again, I experienced the vigor of atomic physics research in Europe. And yet, there is so much variety (sometimes, admittedly, leading to overspecialization) that the attempt of the European Physical Society to submerge all subactivities and locally organized or regional meetings into one giant, centrally conducted ECAMP-like event may be misdirected.

9/29/86

AN INTERNATIONAL MEETING ON INFRARED TECHNOLOGY

by Paul Roman.

The electronics division of the Institution of Electrical Engineers (IEE; UK) organized a highly focused, intensive 3-day meeting, entitled The 3rd International Conference on Advanced Infrared Detectors and Systems. The conference took place in London, UK, from 3 through 5 June at the elegant and well-equipped central offices of the IEE at Savoy Place. About 210 scientists and engineers attended. The majority of the participants was British; next came West Germany. France, Italy, The Netherlands, Norway, Sweden, Israel, and Finland were also represented in the audience, and only six registrants came from the US (even though the American Electron Devices Society was one of the three associate sponsors). An unusual feature of this open conference was that most contributions reported on research sponsored by the relevant Ministry of Defense (MoD). In fact, the majority of the speakers came from either government R&D establishments or from private industry labs with heavy government contract work assignments. University research was almost invisible. The lectures were supplemented by a small exhibit in which some of the speakers' firms demonstrated devices or systems that were talked about; I found this most interesting. The festive keynote-address was delivered by W.D. Lawson (formerly of the Royal Signals and Radar Establishment, Malvern, UK), a highly respected veteran of international infrared (IR) research. In an amusing talk he chose to review the history of British IR research, beginning with Herschel in the 18th Century and ending with a proud recounting of recent MOD-sponsored successes in the area. Regarding future developments, Lawson made two predictions. They were, first, that dual wavelength detectors will get very high attention in the coming years and *second*, that, despite the *enormous* potential of staring devices (with up to 1 million picture elements), for quite a time their development will still lag behind the easier-to-construct scanning devices. Nonetheless, this is the wave of the future.

All other talks were solicited papers; altogether there were 36, and each lasted 20 minutes (including brief discussions). The topics were most efficiently grouped as follows:

1. IR sensors (3 sessions)
2. Radiation effects
3. IR signal processing
4. IR systems (4 sessions)
5. Cryogenics

I review only talks that (surely prejudiced by my interests and background knowledge or lack of it) I found particularly interesting in the areas 1, 2, and 4. But I have the complete texts of all presentations and will be glad to send interested individuals copies of specific contributions in any field. I also have a list of participants.

Detectors and Sensors

Silicon Technology. The first group of talks in the area of detectors was on silicon technology devices. It is probably significant that all speakers came from West Germany.

U. Suckow reported on cooperative *research performed* by scientists at Valvo-Philips and at Messerschmidt-Boelkow-Blohm, related to Schottky-barrier IR charge-coupled device (CCD) focal plane arrays. The researchers developed such arrays with 128×64 picture elements. The device utilizes n-channel CCD shift registers with an interline shift (three-phase horizontal and vertical readout). The detectors are constructed with a thin PtSi layer separated from an aluminum mirror by a layer of Si_3N_4, which has a thickness adapted ideally to a wavelength of 4 μm. The detectors are illuminated from the backside and have an unusually high photoresponse. The quantum efficiency is several percent. In the range of 3.3 to 3.5 μm the blackbody (500 K) detectivity of the devices was found to be about 10^{11} $cmW^{-1}sec^{-½}$ The authors came to the conclusion that the PtSi Schottky barrier diode is a feasible alternative for IR imaging in the 3- to 5-μm range. The main advantages of the complete monolithic construction with CCD readout on the chip are: large density of arrays (may be possibly increased to 10^5); low optical cross-talk; no blooming; acceptable operative temperatures (70 to 90 K); good uniformity of responsivity over the entire chip; and low cost. Future work will concentrate on the increasing of responsivity (use of an optical cavity, optimization of the PtSi layer thickness, reduction of barrier height antireflection coating on the irradiated side). The first application of the currently available prototype was its utilization in a complete thermal imaging system that had a remarkable resolution of 0.1 K.

P. Nothaft (AEG Design Center for Integrated Circuits, Ulm, West Germany) began his related talk on monolithic 2-dimensional (2D) focal plane arrays with CCD readout by discussing the limitations of present-day 2D detector arrays. He pointed out that, since IR detectors with sufficiently high sensitivity require operating temperatures less than 70 K, for a large array in a Dewar one would need an individual vacuum-dense feedthrough for every detector element--clearly an impossible task. The obvious solution is to use a multiplexer, located inside the Dewar. Within the important 3- to 5-μm IR window, Nothaft claimed, the favorite detector candidate is indium-doped silicon (In:Si).

As a multiplexer, a CCD seems to be ideal if monolithic integration is required. He then explained that, in order to improve the filling factor on the integrated chip, the AEG researchers changed the customary layout so that in their design both surfaces of the IR-CCD chip are fitted with electrical and optical components. The IR detectors are located at the lower chip side, whereas the signal processing CCD's are on the opposite side. Double-sided wafer lithography is the requisite technique to achieve this. As a prototype, AEG developed a 32×32 In:Si IR-CCD focal plane array. Details of both the detector and of the readout mechanism were given. In conclusion, Nothaft confidentaly told us that, even though so far wafers of only 1 or 2 inches in diameter were fabricated for monolithic In:Si detectors arrays with CCD readout, we are now on the verge of producing 4-inch-diameter wafers, which will soon allow the development of monolithic IR-CCD's with 10^5 or 10^6 detectors in the focal plane.

Indium-doped silicon devices were also the topic of another talk, presented by J. von der Ohe from Valvo-Philips. This talk discussed In:Si-based devices for thermal imaging. Like the preceeding speakers, Ohe emphasized that even though InSb or CdHgTe offers superior detector performance at higher operating temperatures, silicon devices, at present, have the advantage in the area of effectively developing complete devices which have many pixels of small size, and possess a high filling factor. In a careful exposition Ohe explained how he and his colleagues developed an IR staring array of photoconductive In:Si detector elements. This was a 64×64 array, attached to a CCD readout with low noise, high transfer efficiency, and high operational speed. The imager was, once again, designed for the 3- to 5-μm range; it needs cooling to 50 K; and it has a thermal resolution of 0.1 K.

Other Materials. There were, of course, proponents of detectors based on materials other than silicon. InSb devices got only little attention; but K.D. Werkman (AEG, Ulm, West Germany) made a valiant presentation on behalf of his colleagues in which he described the successful experiments leading to a 64-element InSb IR-CCD device. The researchers' goal was to develop an IR imaging system with high geometrical resolution, hence an IR detector array with performance near the theoretical limit and with high pixel number and density. Werkman explained how the AEG researchers developed a hybrid IR-CCD detector: it consisted of a photovoltaic InSb array with 2×32 detector elements in a staggered array configuration, and of two symmetrical Si-CCD circuits, each with 32 parallel coupling-stages. The IR-CCD hybrids were mounted in a Dewar housing. The bulk InSb material was n-type doped; the p-n junction was formed by Cd indiffusion along the whole surface of the wafer. Separation of the detector elements was achieved by mesa-etching. The specifications of the IR-CCD detector unit are tough:

Integration time: 5-60 μs
Sampling period: 65 μs
Maximal processable charge: 6.6×10^{-11} As
Noise-equivalent charge: 3.3×10^{-16} As
Dynamic range: 70 dB,
Clock frequency: not more than 1.1 MHZ
Detectivity at peak wavelength: greater than 10^{11} cm $\mathrm{Hz}^{1/2}\mathrm{W}^{-1}$
Power consumption (without Dewar): less than 40 mW.

My only criticism of the talk is that it covered only engineering details and no basic science.

Cadmium-mercury-telluride (CMT) detectors were strongly highlighted among non-Si systems. If the conference is representative of current European efforts then I am inclined to say that France has the leading edge in this area, despite the fact that, historically, the British introduced this field almost 30 years ago.

J. Ameurlaine (Société Anonyme de Télécommunications, France) talked about a new generation of CMT photovoltaic detectors for focal plane arrays. To me, the most interesting part of his presentation was when he demonstrated that, while in the 2- to 5-μm band the competition between different systems is still open, the situation is completely different for the 8- to 12-μm spectral band. Here, apparently, the only viable solution is the use of photovoltaic CMT. (Pyroelectric IR-CCD is not excluded, he said, but these systems have low performance characteristics, with the redeeming feature of low cost.) However, there are to date no acceptable monolithic CMT structures for the 8- to 12-μm band, so that hybrid structures win the field. In the body of his talk, Ameurlaine discussed in considerable detail the growth-technology for HgCdTe crystals and the careful planarizing process developed at his institution. The talk was much too process-oriented--and often sounded as a (probably justified) aggrandizing of his firm.

J.L. Tissot represented the research effort of the Infrared Laboratory of LETI (Grenoble, France) in a talk on recent development of photovoltaic CMT detectors and their coupling to CCD circuits. Devices both in the 3- to 5-μm and in the 8- to 12-μm range have been developed at LETI. Both linear and two-dimensional (2D) arrays (the French call the latter "mosaics," a terminology to be recommended) were fabricated and tested. Typical structures produced were: 64×64 arrays on TMOS switches; 2×6 linear systems; 32×32 devices for 3- to 5-μm and for 8- to 12-μm; 4×300 linear arrays coupled to a time-delay-and-integration-mode (TDI) multiplexer CCD. All these devices had a shunt resistance value in excess of 10^8 ohms and, even at a reverse bias larger than -200 mV down to frequencies below 10 Hz they did not exhibit an 1/f noise. The photovoltaic arrays were hybridized on a CCD with the In-bump technique.

Germany also had a good contribution to the CMT effort: H. Maier, representing Telefunken, described a 64-element linear detector system with hybrid IR-CCD readout. The device was constructed for the 8- to 12-μm band. It required cooling to 80 K.

The most scholarly talk in the field of CMT structures was given by a British scientist: M.A. Keenan reviewed UK advances in linear and in 2D CMT-Si hybrid focal plane arrays. This talk represented a cooperative effort of the private firm Mullard (Southampton), the Royal Signals and Radar Establishment (Malvern), and the Royal Aircraft Establishment (Farnborough). The speaker explained that a new Si-multiplexer technology has been developed for performing an integrating and scanning function for IR arrays in the 8- to 14-μm wavelength range. The multiplexer is based on a standard NMOS technology and has significant performance improvements and operational advantages over CCD architectures. Devices have been demonstrated in 2D formats up to 64×64 elements, and also in a 64-element linear module. Currently, a 128×128 device is under development. NMOS technology allows for simplicity of operations, high performance, and wide wavelength range; it is scalable to extremely large arrays. The preparation of NMOS technology devices is simplified because only one, simple, clocking waveform is needed. A mechanism has been developed which allows independent accessing of the CMT photodiodes for detailed assessment. I think that this research deserves close attention in the future.

Most experts in the field will probably not be surprised to hear that hardly any attention was given to pyroelectric detectors. I call attention to the work of S.G. Porter (Plessey Research Ltd., Casswell, UK), who valiantly defended such systems by pointing out the growing need for uncooled thermal imaging devices that require little operating power and no maintenance. Under such circumstances, pyroelectric arrays may be the prime candidates. Porter's talk described recent progress in both linear and 2D arrays. Linear arrays up to 40 elements have been fabricated. They have a thermal resolution better than 0.2 K, and have proved their worth in slow-scanning imaging systems. Two-dimensional arrays in 6×6, 20×20, and 16×16 configurations have also been constructed, without scanning provisions but with a CCD multiplexing readout. Current work concerns the development of much larger 2D arrays. Porter paid special attention to ways designed for avoiding microphonic phenomena. He also explained that the key to success was the development of electrically conductive pyroelectric materials, because with these one doesn't have to use cumbersome high-resistance resistors. (The composition of these novel materials was not revealed--presumably because of proprietary reasons.)

Radiation Effects

The talks in this area were not concerned with radiation-hardening of detectors but rather with questions of determining, modeling, and controlling IR emissivity; and with the modification of IR signatures. IR propagation problems were also discussed.

Emissivity is the key quantity required for the calculation of radiative energy transfer. Military applications, in particular, require emissivity and propagation studies (for example, in target signature interpretation).

I was particularly impressed by two talks that orginated from the West German Research Institute for Applied Sciences (FGAN). The first talk, presented by D. Clement, reported on work done at FGAN's Research Center for Optics (FfO) at Tübingen, and concerned itself with laboratory assessment of camouflage material's effectiveness in the thermal (3- to 14-μm) IR range. Typical camouflage materials are nets, mats, paints, grids; many new composites for these purposes have been recently proposed. Since conventional field testing is lengthy, costly, and hard to reproduce (because the performance of the materials depends strongly on environmental conditions), FfO developed a laboratory-scale test facility. This consists of a parameter test bench (for measuring material parameters), and of a simulator section (used to generate variable environmental loads and to show the direct temperature response).

The central part of the test bench is an IR reflectometer, consisting of a goldplated integrating sphere. The radiation source has a temperature of 1000 K, and the radiation is chopped at 800 Hz. The sphere contains a reference material sample and a sample of the tested material; the reflected and diffused radiation is sensed with an InSb-CMT sandwich detector at liquid nitrogen temperature. Broadband emissivity is measured in the 3- to 5-μm and the 8- to 12-μm range. Further improvements will allow for insertion of continuously variable filters. The addition of a system to determine reflectivity at 0.4- to 1.2-μm is also planned. Thermal conductivity is measured too, in a rather conventional manner. At a later stage the researchers will add a glossmeter in the visible and transmitter/receiver systems at relevant laser and mm wavelengths.

The simulator test bench of the FfO facility is located in a thermally stabilized room. It contains a wind tunnel. Irradiation of the tested materials from the back is done with a large blackbody emitter (up to 200°C). The forward face of the sample can be irradiated by a 4-kW mercury discharge lamp (artificial sun). Two flat cold-shields are used for simulating cold-sky radiation and cold-ground conditions. Temperatures of surfaces are measured with semiconductor devices; while irradiance and wind speed are measured with sensors in the probe plane. Data are automatically logged for subsequent evaluation. The response of the probe material is monitored by two thermovision cameras (one for the range 3- to 5-μm, the other for 8- to 12-μm).

The usefulness of the test facility predicates the possession of reliable models that predict thermal background characteristics. Models are also crucial to calculate atmospheric propagation of electromagnetic radiation for varying meterological conditions. To gain confidence in such models, it is necessary to confront them with careful observations. A presentation by R. Neuwirth, reporting on joint research of FGAN's FfO and FGAN's Research Center for High-frequency Physics (FHP) at Wachtberg-Werthhoven, went quite a way along these lines. Emphasizing the importance of multimode correlation, the talk reviewed experimental studies of visible, IR (3- to 5-μm and 8- to 13-μm), and millimeter radiation (94 GHz). Observations under varying conditions (especially rain and fog) were made at distances ranging from 4 to 12 km, and were compared with various models. One of the major results was that, using the rainrate as a simple meterological parameter, existing models work very well. Current investigations on a 3 to 5 km range (over land) will be used to evaluate models that include variations of raindrop size and inhomogeneity over the range.

Systems

The talks presented in these sessions were, naturally, rather technical and, because of classification, operational data could rarely be revealed. Since, in consequence, I found the talks somewhat vacuous (and also because I am rather out of my depth in this field), I shall give only a very sketchy characterization of a few selected talks.

There were two presentations concerned with combined visual/infrared imaging surveillance systems for marine applications. The first reviewed the year-long achievements of E.A. Richards (Admiralty Research Establishment, Portsmouth, UK) in the development of the "ARE SEAWATCH" system. This is, he emphasized, still a civilian research tool, with untested military specifications, but it is a robust and simple design, readily capable of replication or modification. The heart of the system is the electro-optical imager assembly. It consists of a color daylight TV camera, a low-light TV camera, a CCD (black/white) TV camera, and an 8- to 14-μm thermal imager (which has a large Ge lens in front). All these imaging devices are housed in a common enclosure and are mounted on a pan-and-tilt head. The video-signals generated by the imagers are transmitted either by a microwave link (up to 20-km transmission), or a telephone line (effective range of slow transmission about 500 km). One of the interesting research results is that the thermal imager is capable of better haze-penetration than the CCD camera, and it also gives additional information relating to otherwise invisible thermal emissions from the target.

H.O. Nielsen (NEA-Lindberg A/S, Denmark) gave a closely related talk on a system called IVISS--short for "infrared and visual imaging surveillence system". This is also a land-based system, optimized for the identification of passing vessels and for the transmission of the collected image-information via ordinary telephone lines. In order to achieve high spatial resolution and high sensitivity (making the system ideal for identification over long distances) both the optical and the 8- to 14-μm IR channel operate on a slow-scan principle. The IR detector is an 8-element SPRITE detector, cooled, at present, by a Joule-Thomson cooler (but a novel Stirling machine will soon take its place). The visual channel is based on a 1024-element CCD array, thermoelectrically cooled. A resolution of 0.1 mrad, and an IR sensitivity of 0.1 K was achieved.

Multichannel instrumentation was the topic also of another talk, presented by G. Gauffre on behalf of Aerospatiales, Chatillon, France. He reported on a system which can simultaneously collect data in two IR wavebands (3- to 5-μm and 8- to 12-μm) and two microwave wavebands (35 GHz and 94 GHz). This is a downward-looking helicopter-borne system. The IR and microwave parts of the system have a comparable field of view, resolution, and acquisition speed. The IR device has, of course, two detectors side by side in a cryostat; for the 8- to 12-μm band a CMT detector is used, and for the 3- to 5-μm band an InSb detector. The instantaneous field of view is 2 mrad. The scanning mirror is driven by a motor controlled by a microprocessor which includes a clock. For each line, each channel is sampled 240 times and digitized with 12 bits resolution. The radiometric accuracy limit is a remarkably low 0.03 K in the 8- to 12-μm band and 0.08 K in the 3- to 5-μm band.

The interesting report of C.I. Coleman (Marconi Defense Systems Ltd., UK) concerning experiments with laser warning systems did not quite belong to this particular conference on novel IR technology since, as he freely admitted, the present system is designed only for the 0.4- to 1.1-μm range, with an emphasis on ruby and classical Nd:YAG laser radiation. However, the way of thinking at Marconi is to develop laser warning systems that are not specific for a particular wavelength. In his very clear review, Coleman first explained that laser detection on the battlefield is made difficult by two causes: first, the presence of radiation competing with laser fields (sun, moon and stars, airglow, lamps and searchlights, gun-flashes, explosions); and second, environmental effects (turbulence, extinction, and scatter). In the sequel, Coleman analyzed the specifications that a laser detector should satisfy; and finally, he gave a somewhat vague description of Marconi's current experimental system. It appears that the system is based on position-sensitive silicon detectors. These give rather precise bearing determination. This imaging system can yield laser bearings to a precision "of a small fraction of a degree, in a field of view of a few tens of degrees." There is also a non-imaging system in the package, with a panoramic capability, but with a resolution of only 15° to 90°. Experiments are also conducted with interferometric configurations for coherence-analysis (such as a pair of different-length etalons followed by two detectors whose output is then combined). Future plans focus on extending detection to higher wavelengths, up to the CO_2 laser's range. (The speaker claimed that CO_2 lasers are gaining battlefield importance--even though it is unlikely that this would be in the area of range finders or designators.) Other experiments will aim at pulse-length discrimination. Finally, it may be possible to detect scattered (as opposed to direct) laser radiation. Unfortunately, I could not comprehend the principle of this scatter-detecting laser warning system, but I understand that the idea is subject to a British patent application.

There were three talks which addressed the topical area of active IR devices. Since it would loosen the coherence of this report if I went into details, I will only give a summary account. A group from the Royal Signals and Radar Establishment (Malvern, UK) presented latest developments in the realization of a frequency modulated continuous wave CO_2 laser IR Doppler radar. Another group of scientists from the same institution presented research results on the development of a continuous wave CO_2 laser heterodyne rangefinder into a system which is capable of both active imaging and remote vibration sensing. (The latter aspect allows for obtaining useful discriminants to enhance objects previously acquired.) The third talk came from the firm of Crouzet SA, France, and reported the construction of a functional CO_2 laser Doppler anemometer breadboard (built around a Michelson interferometer, with a Bragg cell in the reference arm.)

Finally, I want to mention the only paper presented by a North American: L. Pelkowitz (Computing Devices Company, Canada) talked about automatic tracking of IR targets. The topic of the research is really not in the area of IR devices, but rather belongs to the exciting domain of dynamic, real-time image analysis, with a goodly pinch of artificial intelligence thrown in. The prototype system Pelkowitz described is presently a brassboard realization, but tests have proven that the algorithms used (they are essentially template-matching techniques, without correlation calculations) allow for handling a wide range of targets and backgrounds as well as a moderate amount of random sensor motion. Figure 1, which is a block diagram of the autotracker's functional decomposition, should give a good overview of the system.

Concluding Observations

This was a successful, well attended, relaxed, focused meeting. The low-key, quiet efficiency of British organization was evident throughout. Personally, I much enjoyed the civilized, dignified atmosphere--so rare these days at professional meetings. I also found it gratifying that there were no parallel sessions and that, mercifully, no distraction was provided by so-called "poster presentations."

I understand that the number of participants was 30 percent less than that of the two preceding conferences (1981 and 1983). I was told that one of the major reasons is that these days it is almost impossible to get US speakers on sensitive topics (if they are to be presented at open meetings).

Indeed, it must have been quite difficult to organize an open meeting with major relevance for military applications. In this context I mention that several participants felt it regrettable that spin-off into civilian applications is still minimal. In particular, many people thought that, as evidenced by this

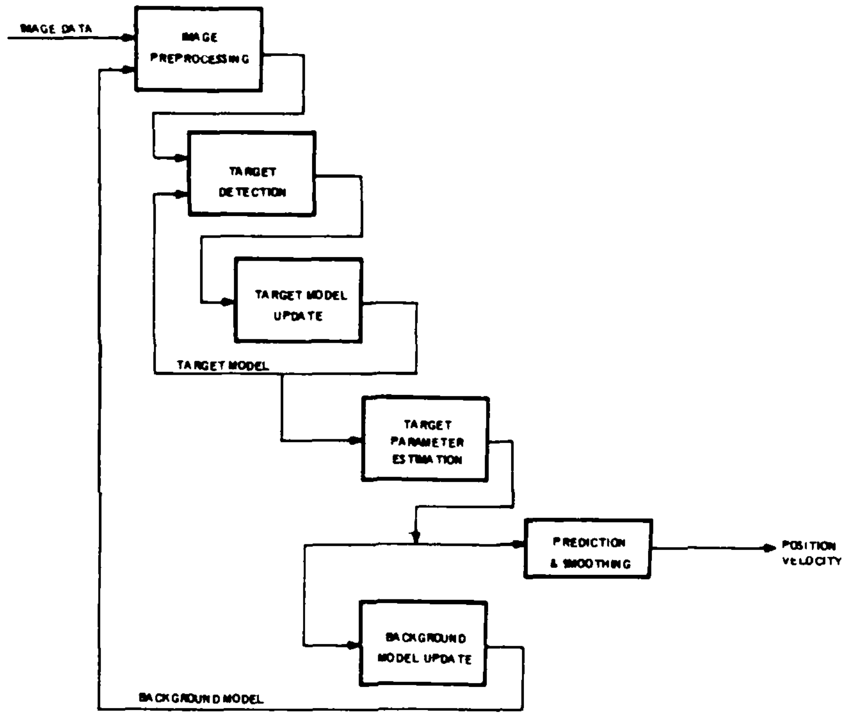

Figure 1. Autotracker system block diagram.

conference, there is little effort expended in the development of cheap and simple systems, such as pyroelectric devices.

An interesting aspect of the conference was that, despite domination by the contributions on detectors, it became clear that there are still many new avenues to be followed in this field. On the other hand, it was odd that no mention was made of sensors off the beaten path, such as HgMnTe materials, or more speculative detectors, based on strained layer superlattices.

Finally, one got the impression that, notwithstanding recent progress in laser imaging or range finding, it is unlikely that active IR devices will compete successfully with thermal imaging systems--at least not for quite a time to come.

9/29/86

News and Notes

ONRL'S RECOGNITION OF THE 40TH ANNIVERSARY OF ONR

In addition to celebrating ONR's 40th anniversary with a special supplement in the October 1986 issue of *ESN*, ONRL held a meeting of ONRL alumni and staff in London from 6 through 10 October. While the meeting itself was part of the recognition, much time was devoted to a hard look at ONRL in its past, present, and future: 19 alumni joined the present staff in a series of introductions, presentations, and give-and-take discussion.

Equally important to the formal discussion of the first 2 days were the individual meetings between the ONRL staff and alumni during the following days. Also contributing to the sense of mission continuity and improvement were the social activities. Attendance of staff, alumni, spouses, friends, and children was approximately 80 persons at the welcome social on Monday, the 6th; 67 at the pre-dinner gathering on Tuesday; and 54 at the no-host dinner. Finally, 12 ONRL staff, alumni, and spouses ended the week with a coach tour of North Wales.

That week, set aside to honor ONR's 40th anniversary, successfully brought together those who have served and are serving the Navy through the Office of Naval Research Branch Office, London. The high quality of the staff, then and now, was evident by the tone of the discussions that included incisive as well as general comments about ONRL and suggestions for the future of the ONRL office.

The overwhelming conclusion was that the 50th anniversary of ONR should be recognized by ONRL in London, and be patterned after the 40th.

David L. Venezky
10/15/85

FIFTH EUROPHYSICAL TOPICAL CONFERENCE, LATTICE DEFECTS IN IONIC CRYSTALS

The Fifth Europhysical Topical Conference, Lattice Defects in Ionic Crystals (LATDIC-86) was held from 8 through 12 September 1986, at San Lorenzo El Escorial (Madrid), Spain. Organized under the auspices of the European Physical Society, this conference was the fifth in a series dealing with the same topic (earlier meetings were held in Marseille in 1973, Berlin in 1976, Canterbury in 1979, and Dublin in 1982). Financial support was provided by some 14 sponsors, spanning a spectrum of Spanish governmental, academic, and industrial activities, as well as the US Army Research, Development, and Standardization Group, UK. The total attendance of 235 was truly international in character: in addition to 50 delegates from the host country, there were 27 from France, 23 from the West Germany, 20 from the US, 17 from the UK, 15 from Italy, and 13 from the Eastern Block including the USSR, Poland, Hungary, Rumania, and Czechoslovakia. Other countries represented by one or more delegates included Israel, Japan, Belgium, the Netherlands, Greece, Finland, Switzerland, Austria, Ireland, Mexico, Venezuela, Brazil, Argentina, Canada, India, Australia, and South Africa. The proceedings will be published as a special issue of *Crystal Lattice Defects and Amorphous Materials*.

LATDIC-86 was envisaged by the organizing committee to be a turning point in the series, which had initially carried a heavy emphasis on alkali halides. Thus, while there was to be a continued concern with the fundamental problems of defect physics, it was hoped to extend the scope of the conference to attract scientists working in the defect aspects of a number of rapidly developing new areas in both basic and applied physics. It appears that the conference was quite successful in achieving this goal, as reflected in the substantial number of papers dealing with refractory oxides for nuclear fusion first-wall applications, glasses, and ceramics for nuclear waste storage; fast, ionic conductors for solid-state batteries; and materials systems for optoelectronics and solid-state lasers. In the same spirit, contributions dealing with defects in amorphous insulating materials were explicitly encouraged for the first time. Perhaps it was partially due to the title of the conference that the actual number of papers dealing with glasses *per se* was limited to a handful. This is not likely to be the case in the future, however, as it was announced that the next conference in the series would take place under the more encompassing title "Lattice Defects in Ionic Materials."

The conference opened each morning with one or more plenary lectures in the historic 16th century monastery of El Escorial. The remaining sessions were held in a nearby modern retreat facility which included the comfortable lodging units and dining hall used by nearly all attendees. This arrangement contributed to the high degree of interaction among the delegates, which characterized the meeting. In all, 18 plenary lectures were presented, together with 80 contributed oral papers in two parallel sessions and 134 posters. Session titles (numbers of papers) were as follows: Theoretical methods & computer simulation (21); Radiation damage (35); Photoeffects (9); Dosimetry (9); Dielectric properties (13); Transport (21); Fast ion conductors (12); Spectroscopy (43); Clustering (7); Optoelectronics (14); Solid-state lasers (10); Extended defects and nonstoichiometry (15); Dislocations (11); Minerals (12). This great diversity of topics, many of them covered in parallel sessions, clearly strains the capacity of a single individual to summarize in any balanced fashion. Therefore the following paragraphs should not be regarded as other than a few of my personal impressions.

Perhaps there would not be widespread disagreement with the impression from LATDIC-86 that basic science is still as important as ever in underpinning the long-term development of future applications. Despite indications that fundamental research is under as much budgetary pressure in Europe as it is in the US, it was apparent that the Europeans have been carrying out some superb basic research, much of which will clearly impact on the technologies of tomorrow. An important example of this is in the area of wavelength-tunable color-center lasers. The group of J.M. Spaeth (University of Paderborn) has demonstrated by optically detected electron spin resonance (ODESR) that the lasing species in Tl-doped alkali halides is in fact the same as the Tl^0+vacancy center which was so thoroughly characterized in the ground-state-ESR experiments of the group of D. Schoemaker (University of Antwerp). Drawing on the insights derived from their earlier studies of the $Tl^0(1)$ centers, Spaeth and coworkers reported at LATDIC-86 the "engineering" through basic research of a promising new solid-state laser system based on room-temperature-stable $Pb^+(1)$ centers in alkaline earth fluorides. The Antwerp group also reported on studies of the structures of a variety of $Pb^+(1)$ centers in alkali halide hosts.

One also could take note of the considerable activity in color center research in Spain. An opening overview by F. Jaque (University of Madrid) on spectroscopic tools to study clustering in alkali halides was followed during the course of the week by numerous other talks and posters, largely from universities in Madrid, Zaragoza, and Santander, detailing in-depth investigations of defects and impurities in a variety of insulating materials ranging from the alkali halides to the perovskites to such photorefractive materials as $LiNbO_3$. As pointed out by F. Agullo-Lopez (University of Madrid) and K.A. Muller (IBM Zurich) the photorefractive effect in $LiNbO_3$ appears to be intimately associated with the presence of impurities (particularly iron) and lattice defects.

Defects and photorefractive phenomena in electro-optic crystals also constitute a major research interest elsewhere in Europe. An overview lecture on the topic was presented by E. Kratzig (University of Osnabruck). Among several other contributors from Osnabruch, Juppe and Shirmer described ESR and optical studies of both Ti-doped and reduced, undoped $LiNbO_3$. P. Mazzoldi and A. Carnera (University of Padua, Italy) elaborated on the structural characterization of optical waveguides produced on $LiNbO_3$ by Li_2O out-diffusion, ion exchange, or Ti in-diffusion. Several other papers on this class of materials represented work by authors from France, Morroco, England, and Hungary.

The role of defects in transition-metal-doped tunable lasers was reviewed by G. Huber (University of Hamburg). In contrast to the case of ruby, Cr^{3+} in alexandrite, emerald, and some fluorides, garnets, and tungstates exhibit broad-band fluorescence capable of supporting laser action from ~700 up to ~1100 nm. It was pointed out that the efficiency of these and other tunable solid-state lasers can be severely degraded by defects which can be created by intense optical pumping or which can arise from impurities. Huber emphasized that to date little is known about the detailed natures of these defects, thus underscoring one of the driving forces for the continued prosecution of the type of research which was the focus of this conference.

Indeed, considerable progress in the fundamental mechanisms area was reported at LATDIC-86. R.T. Williams (Wake Forest University, Winston-Salem, North Carolina) teamed with K.S. Song (University of Ottawa, Canada) to propose a revolutionary model for exciton self-trapping in alkali halides involving a spontaneous relaxation to an off-center configuration equivalent to a nearest-neighbor F-H pair. As apparent from the vigorous discussion which followed, the new model, if confirmed by further investigation, will greatly alter our understanding of radiolytic lattice defect formation in the alkali halides and quite possibly wider classes of dielectric materials. Quartz and silica comprise a class of insulators which were perhaps underrepresented at this meeting given their widespread application in electronics, frequency standards, and optics. However, Hayes and Jenkin (Clarendon Laboratory, Oxford) provided a tantalizing piece of the puzzle of exciton self-trapping in SiO_2 by showing that self-trapped holes are either not formed in quartz or are not stable at 4 K.

David L. Griscom
Naval Research Laboratory
10/16/86

HIGHLIGHTS FROM THE 8TH INTERNATIONAL CONFERENCE ON SOLID-STATE DOSIMETRY

The 8th International Conference on Solid-State Dosimetry was held at St. Catherine's College in Oxford, UK, from 26 through 29 August. This meeting attracted scientists and engineers from all over the world, with about 175 participants. The 120 papers presented at the conference covered a wide variety of topics relating to dosimetry. These ranged from the basic experimental and theoretical mechanisms involved in thermoluminescent dosimeter materials to the more applied aspects of personnel dosimetry and instrumentation.

Drs. Abbundi, Brown, and Mathur (Naval Surface Weapons Center [NSWC]) presented two papers entitled: "Optical Absorption and Thermoluminescence in Calcium Fluoride Doped with Manganese and Cerium" and "Optically Stimulated Luminescence in MgS:Ce,Sm." These experimental investigations dealt with the study of radiation-induced defects in thermoluminescence device (TLD) material as well as an effort aimed at developing a new dosimeter material which can be read without heating the phosphor.

Dr. A. Haque (Polytechnic of the South Bank, London, UK) presented a paper dealing with the use of 256-k DRAM computer memory chips as a dosimeter. The potential use is in the detection of fast neutrons which are converted to alpha particles and are then sensed by the DRAM in the form of a bit flip. This work was pioneered at NSWC some 4 years ago and the Navy is presently funding research and development in this dosimeter.

The technique of using a CO_2 laser to rapidly heat a phosphor continues to draw considerable interest. Drs. P. Braunlich (International Sensor Technology, Pullman, Washington) and J. Gasiot (Université des Sciences et Techniques du Languedoc, Montpellier, France) each presented two papers on the subject. The technique results in such a large increase in the signal-to-noise ratio that a much greater sensitivity is achieved than under the present method of reading a dosimeter. The method also holds the potential for measuring fast neutrons. Both of these areas are becoming of increasing interest for personnel dosimetry.

Data on the defects in $CaSO_4$:Dy were presented by Dr. T. Stoebe (University of Washington, Seattle). His electron spin resonance and absorption results clearly show that thermoluminescence sensitivity is greatly influenced by the presence of trace impurities in this material. These conclusions were echoed by Dr. S. McKeever (Oklahoma State University, Stillwater); working on CaF_2:Mn, he showed that good sensitivity in this phosphor requires the absence of trace rare earth ions.

A theoretical model to account for the anomalous fading in TLD's was presented by Dr. R. Templer (Oxford University, UK). His new mechanism involves subconduction band transitions via an excited state shared by a trap-luminescence center pair. This leads to a prediction that a transition from a stable level to the thermoluminescence exists and the unstable component may be removed either with low-energy thermal or optical pretreatments. This model seems to remove some of the discrepancies which exist when one attempts to explain the observed anomalous fading simply by a quantum mechanical tunneling of trapped charge to nearby recombination sites.

In an invited talk Dr. G. Portal of France first gave a historical overview of the development and uses of the most popular phosphor materials being used today for personnel dosimetry. He then talked about the potential use of several new materials such as CaF_2:Tm and LiF:Mg,Cu,P which appear to have much greater sensitivity than the LiF presently used. However, he stressed that the most important aspect of personnel dosimetry is reliability. He concluded his remarks by emphasizing, as did several other speakers, that there is an increasing need to improve dosimeter materials. This can be accomplished by the manufacturers' improving the quality of the phosphors they produce but, more importantly, the decline in basic research which has occurred over the past several years must be reversed. The relatively small commercial market which exists for phosphor material means that the development of new dosimeters is limited to universities and government laboratories.

R.J. Abbundi
Naval Surface Weapons Center
10/29/86

CONTROL THEORY GROUPS AT VIENNA AND GRAS

There are two technical universities in Austria, one at Vienna and the other at Gras. I visited both of these universities during September 1986 as part of an effort to assess control theory in Austria. Since I believe that excellent computer capacity is necessary for work in the field of control theory I normally visit the computer center as well as investigate the individual department computer facilities of the institutions I visit, and that is what I did in this case.

The Technical University of Vienna

The Technical University Vienna was founded in 1815 as a polytechnical school; it was given its present name in 1975. There are five faculties: civil engineering, mechanical engineering, architecture, electrical engineering, natural sciences (mathematics, chemistry, technical physics, geodesy), and computer science. At the present time the university has 13,100 students, 175 professors, 110 associate professors, and about 700 scientific assistants. All members of the staff engage in teaching as well as research. The degrees awarded are Diplom-engineer and Doctor of Technical Sciences. Although earning a Diplom-engineer requires a nominal 5 years, typical individual programs can last from 6 to 7 years. The doctoral program is more strictly an academic degree in Austria and requires an additional 3 to 4 years.

My visit in Vienna consisted of a review of the university's computer facilities, a visit with Professor Weinmann's group in control theory, and a visit to the robotics laboratory. The computer facilities are excellent. Within the last few months a new Cyber 180-860 has gone on line. There are over 300 terminals attached to the mainframe, which has 16 Mbytes of main storage and almost 12 Gbytes mass storage. Typical software consists of IMSL, SPSS, and a small graphics package called ERLGRAPH. Further attachments consist of a VAX computer and some work stations. The entire system is coupled by an ethernet. Part of this net includes a NAS AS9160 and a hybrid EAI computer which uses SIMSTAR. Each of the departments in the Technical University has microvax computers which are used locally by students and for research purposes. Also available in the departments are PC computers for student use, but, unlike his counterpart in America, the individual researcher or professor does not have a PC on his desk. The mainframe does not have extensive graphic capability, and I believe that to exploit its full potential more graphics software is needed.

Professor Weinmann's group is somewhat small. I had an opportunity to talk with Dr. H. Homole and Mr. R. Noisser, who are two of his assistants. The laboratory is well supplied with computer equipment, having a microvax 750 and several PC's for student use. About 100 students take the elementary controls courses and perhaps 20 take the advanced sequence. Dr. Homole has recently developed a fairly extensive set of interactive computer programs for solving control problems. This is certainly a necessary prerequisite for solving modern control problems and will be quite helpful in any future research emphasis. Computer programs of an interactive type have been discussed at length in a report on the IFAC conference to be published soon in *ESN*. European activity in this area is about a year or two behind that in America. Weinmann's group is just beginning research work on eigenvector assignment as a tool for design of multi-input/multioutput problems. One of the recent research publications of this group (Kacnogla and Noisser, 1986) deals with time series controllers.

There appeared to be a large emphasis on teaching in the department, perhaps a bit to the detriment of research oriented work. The entire teaching program is laid out in three books on control theory by Professor Weinmann; these form the basis for the control theory option at the Technical University. The first volume is devoted to classical control theory; the second to optimal control, nonlinear control, and adaptive methods; the third to stochastic theory, Kalman filter, and robust control.

The student body in control theory has recently increased, most likely due to the emphasis being placed on control theory by a new federal program which is designed to further modern control methods throughout the entire technical community. There is a strong federal drive to have younger people trained in controls applications at both the technology and university levels. This federal program has developed a complete university and technical school curriculum in controls application and theory.

The robotics laboratory, started in about 1981, has at present, some 120 students. Professors K. Desoyer, P. Kopacek, and I. Troch are involved with the working group on industrial robots and manipulators. There are three robots or arms in the laboratory: a Pobk0-01, an HRA 933, and a large IGM (listed in order of increasing sophistication). The first robot is controlled by a commodore 64, which the students use to learn programing of robots. The second machine has an IBM PC as a controller, and the third machine has a PDP 11. The three professors listed above have published a book (Desoyer et al., 1985) on robots and they have an extensive list of over two dozen publications (Desoyer et al., 1985) in the field. The publications are directed at modeling, development of advanced control laws, and the use of microcomputers in industrial robots. The present program appears to be somewhat academic and there is not a strong connection with industrial companies. This lack of interaction with industry could hamper future development of the laboratory.

The Technical University of Gras

In my visit to Gras I talked to the control group at the Technical University. Professor Schneider, head of the laboratory, is assisted by Drs. A. Hofer, F. Gausch, and K. Schlacher.

The group has developed a very competent computer package involving the simulation, analysis, and design of control systems. The programs in this

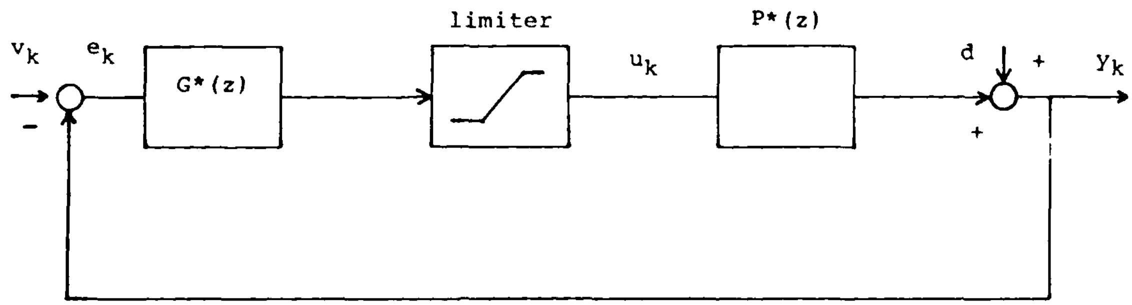

Figure 1. Typical circuit for nonlinear digital control problem.

package have the acronyms DASP (Gausch, 1986) and LINSY (Hofer, 1986). The package, which has been sold to an industrial concern in Austria, is not menu-driven, as are most such programs. Thus, use of the programs requires one to learn a set of specific commands. The advantage that this has is that the program is faster. I had an opportunity to work with the program and found it very well constructed from an input-output viewpoint. It was also very easy to change the system under study. As with most such programs one can obtain essentially all the classical analysis needed in a controls design problem. The programs are now written in Fortran and operate on the department HP 9000. It can also run on the IBM PC XT and VAX 11. I did not have an opportunity to consider the algorithms used in the program. Future work will extend the program to multivariable systems.

Other research work in the department is mainly directed at systems with nonlinearities. Most of this work is published in German (Schneider, 1986; Sandholzer and Hofer, 1982) with some in English (Gausch, 1985). The research work of the department normally involves a digital control circuit with a nonlinearity such as a limiter in the circuit. Thus a typical control system would be like that shown in Figure 1, where it is desired to obtain $G^*_{(z)}$ given certain constraints. A typical constraint might be on the size of the control variable u_k, i.e., $u_k<u_{max}$ with a further constraint on the size of the errors signal:

$$| r_k - y_k | < \varepsilon$$

This is the so-called "Hauptproblem" of the institute, and the researchers have analyzed various aspects of the problem in some dozen publications in *Automatisierungstechnik at* from 1984 to 1986.

Conclusion

The computer facilities in the control area in Austria are excellent. The research activities are not extensive due to an emphasis on teaching, caused in part, at least, by the small number of people involved. The research that is being done is of reasonably high quality but limited to a specific problem area. The Austrian government has developed a comprehensive program in the controls area and is encouraging young people to enter the field. One can therefore expect increased activity in the controls field in the future in Austria.

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Daniel J. Collins
10/17/86

FRENCH SUPERSONIC COMBUSTION RESEARCH--REVISITED

Recently I had an opportunity to visit A. Mestra at Office National d'Études et de Recherche Aerospatiales (ONERA) in Palaiseau, E. Esposito at the École Centrale des Arts et Manufactures in Paris, and R. Borghi at the University of Rouen, who were all active in French supersonic combustion research in the 1960's. Given the resurgence of interest in this research in the US a brief historical review of their work might be of interest.

Both Mestra and Esposito looked at hydrogen and kerosene as fuels. Esposito's facility was the less ambitious of the two, having a maximum stagnation temperature of only 1500 K, which was obtained in a kerosene-fueled preheater. After adding oxygen to replenish that consumed in the preheating process, the fuel (hydrogen or kerosene) was injected into a 2.7-Mach-number flow produced by a supersonic nozzle. The fuel began to burn immediately downstream of a Mach disk created by the converging walls of the test section. A small region of subsonic flow, which acted to stabilize the flame, was produced behind the Mach disk. A few Mach-disk diameters downstream, the flow was once again totally supersonic.

Mestra's facility (Mestra and Viaud, 1964), which I would judge to be about the same scale as Esposito's, had a much higher stagnation temperature (than Esposito's) and roughly simulates the combustor of a Mach 6.4 vehicle at 34 km altitude (see Figure 1). This was achieved by using a conventional kerosene-fueled preheater and a hydrogen-fueled main heater which was capable of bringing the temperature up to a maximum of 2400 K. As in Esposito's facility, oxygen was added to make up for that consumed in the heating process. Mestra looked at combustion in a free jet, and a divergent, constant-cross-section, and annular burner. The same fuel injector was used for both kerosene and hydrogen; it consisted of a tulip-type injector/flame-holder in which the fuel was injected upstream of the petals. In the case of kerosene the petals acted as vaporizors. The injection tube which formed the center of the test section was 10 mm in diameter and the test section itself was 90 mm in diameter. The fuel was burned at near stoichiometric conditions. In the annular burner the hydrogen was admitted to the test section in a coaxial fashion such that the pressure of the fuel jet equalled that of the surrounding air. This resulted in a Mach number for the hydrogen jet of approximately 1.6, compared with a Mach number of 2.5 for the air. Discrete injection was also tested by employing a strut-like injector with trailing edge slots. Various combustor lengths (from 50 to 200 cm) were also tested in order to properly size the combustor and injector geometries.

Mestra used another facility; this one had an electric arc heater. Air, passed through the angular gap between the electrodes, allowed temperatures of 4000 K to be reached, which simulates Mach 12 flight speeds. This facility used a water-cooled, constant-cross-section test section having a Mach number of 3. The purpose of the test was to look at the effect of inlet Mach number on combustor performance using both hydrogen and hydrocarbon as fuels.

In this facility R. Borghi (who was then at ONERA) carried out a series of tests (Borghi, 1971) in the arc heater facility in which methane was burned in a preheated planar airstream. Concentration measurements of the combustion products and stagnation temperature were made at three downstream locations. By means of a 3-MW electric-arc heater, the air was preheated to 2700 K before combustion. (See Figure 2.) The test section Mach number was 3. The methane was injected at the airstream pressure and parallel to the airstream. The temperature was in some cases increased by means of a methane preheater to 790 K; however, no effect on the results was seen. Since the flame intermittency was of particular interest, a motion picture camera was used to photograph the flame at film speeds up to 50 images per second. The length of tests available in this facility was approximately 4 seconds. In a subsequent numerical calculation of the combustion process by means of a one-step reaction model, a mixing length turbulence model and a parabolic (Patankar-Spalding) integration method (1971), Borghi found that the mixing and the combustion process could be satisfactorily simulated if the turbulence and combustion models were properly adjusted.

Although some related work was continued (Borghi et al., 1973; Taran et al., 1973; Borghi and Charpenel, 1972; Hirsinger, 1972) support for supersonic

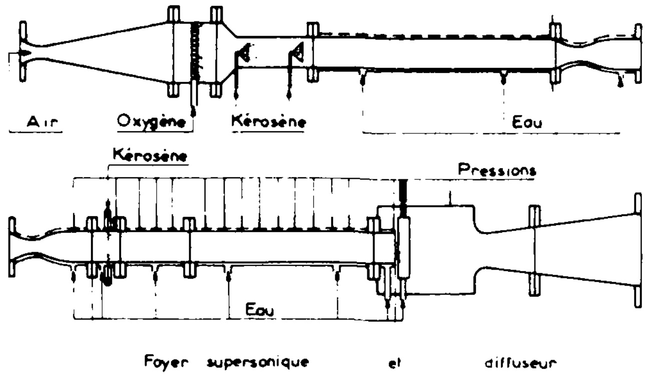

Figure 1. Mestre's kerosene-preheater combustor.

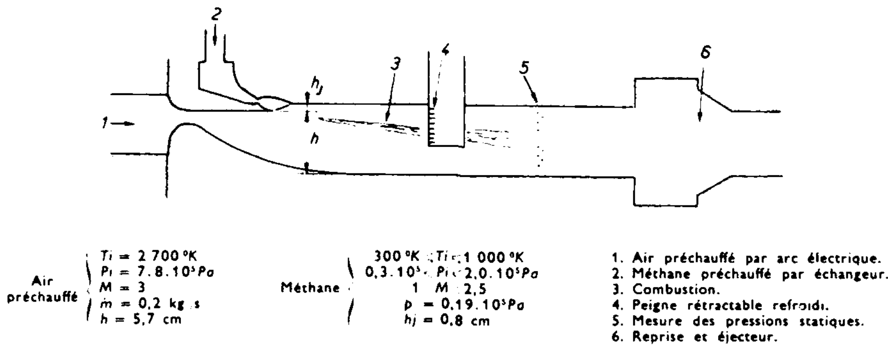

Figure 2. Borghi's arc-preheated combustor.

combustion research in France, just as in the US, declined rapidly in the early 1970's and work in this area was stopped.

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Eugene F. Brown
10/8/86

CALLS FOR PAPERS: SIX COMPUTER SCIENCE MEETINGS

1. The Netherlands Post-Telephone-Telegraph Office is sponsoring a meeting, 6 through 10 April 1987 on SDL, the internationally standardized functional specification and description language for the telecommunication field. The 3rd SDL Forum will be held in The Hague, and the focus will be on applications, tocls, and future trends. Contact posthaste: The Organizing Committee, P. Tilanus, DNL, PO Box 421, 2260AK Leidschendam, The

Netherlands. Because of the short deadline for submissions, it may be better to phone Tilanus at the number (31) (70) 755797.

2. The Information Processing Association of Israel is organizing an International Working Conference on the Social Implications of Robotics and Industrial Automation. The conference will be held in Eilat, Israel, 14 through 17 December 1987. The conference will also cover different aspects of artificial intelligence, expert systems, and manpower training. For information write to: Conference on the Social Implications of Robotics, PO Box 29313, 61292 Tel-Aviv, Israel.

3. The 13th International Conference on Very Large Data Bases will take place at Brighton, UK, 1 through 4 September 1987. Topics will cover, among other subjects: data models, design, distributed bases, optimization, security, knowledge base representation, implementation, object oriented methods, and logics. Papers should be submitted (from American addresses) to Mr. W. Kent, Hewlett-Packard, 1501 Page Mill Road, Palo Alto, California 94394; all other enquiries ought to be addressed to Miss C. Edginton, Manager, BISL Conference Department, The British Computer Society, 13 Mansfield Street, London W1M 0BP, UK.

4. The Seventh Meeting on Protocol Specification, Testing, and Verification will be organized by IBM Research Laboratory and held in Zurich, Switzerland, 5 through 8 May 1987. Contact urgently: IFIP Protocol Symposium, IBM Zurich Research Laboratory, 8803 Rüschlikon, Switzerland, or better, phone (41) (1) 724-8433.

5. Computerized Assistance During a System's Life Cycle is the title of a meeting to be held in London, UK, 19 through 22 September 1988. The conference will have three separate but related themes: Automatic Aids for Systems Analysis and Design; Approaches to Automated System Generation; and Integrated and Automated Analysis, Design, and Construction. Contact: BISL Conference Department (CRIS 88), The British Computer Society, 13 Mansfield Street, London, W1M 0BP.

6. Finally, a conference for those interested in exotic lands: In cooperation with international organizations, the Computer Association of Nigeria will organize an International Conference on Computers and Communication. This, which will take place 29 April through 1 May 1987 in Abuja, will focus on issues of digital computation: standards, techniques, strategies for development, prospects, and problems. Contact: Professor S.B. Jaiyesimi, Department of Computer Science, University of Ife, Ile-Ife, Nigeria.

Paul Roman
9/26/86

CALL FOR PAPERS FOR EUROPEAN MEETINGS ON SEMICONDUCTOR AND SURFACE SCIENCE

1. The 12th International Conference on Amorphous and Liquid Semiconductors (ICALS) will be held in Prague, Czechoslovakia, 24 through 28 August 1987. While all aspects of noncrystalline semiconductor physics will be covered, special emphasis will be on new concepts, approaches, and fundamental (as opposed to technological) aspects of devices. Contact: Dr. Jan Kocka, Institute of Physics, Czechoslovakian Academy of Science, Na Slovance 2, 18040 Praha 8, Czechoslovakia.

2. The 19th International Conference on the Physics of Semiconductors (the one following the mammoth Stockholm meeting in August 1986) will be held in Warsaw, Poland, 15 through 19 August 1988. It will be cosponsored by IUPAP (the original sponsor of these meetings) and the Polish Academy of Sciences. The emphasis will be on new and rapidly developing areas of basic research. For information: Dr. Jacek Kossut, Institut of Physics, Polish Academy of Sciences, 02-668 Warsaw, al. Lotników 32/46, Poland.

3. The 15th International Conference on Defects in Semiconductors will take place in Budapest, Hungary, 22 through 26 August 1988 as a satellite meeting of the Warsaw conference (noted in 2, above). This working conference intends to confront all aspects of semiconductor defect science and technology. Conference chairman: G. Ferenczi, MFKI, P.O. Box 76, H-1325 Budapest, Ujpest 1, Hungary.

4. The 5th Oxford Conference on the Microscopy of Semiconductor Materials will be sponsored by Oxford University, England, and be held 6 through 8 April 1987. Principal topics will include properties of as-grown semiconductors, lattice defects and impurities, processing treatment effects, influence of structural defects on electronic properties, dislocations, superlattices, microanalysis, and electron beam testing of devices. For information: Dr. A.G. Cullis, RSRE, St. Andrews Road, Great Malvern, WR14 3PS, UK.

5. The Fifth Conference on Semi-Insulating III-V Materials will be held

in Malmö, Sweden, 1 through 3 June 1988. Topics will cover growth of bulk semi-insulating crystals, deep quantum levels, annealing of defects, applications of semi-insulating materials in devices, and other related fields. Special emphasis will be on the use of semi-insulating substrates for optoelectronic integrated circuits, and on epitaxial growth of semi-insulating materials (including techniques for vertical and lateral isolation). Inquiries should be addressed to P. Omling, Department of Solid State Physics, University of Lund, Box 118, S-22100 Lund, Sweden.

6. The Third International Conference on Modulated Semiconductor Structures will take place 6 through 10 July 1987, at Montpellier, France; but the preliminary brochure insists that immediate, posthaste notification is required of anyone who wants to participate (submit name, organization, function, full address, whether you plan to submit a paper [proposed title] and what kind of hotel reservation [from 2 to 4 star, single or double] you desire). The ostensive reason for the haste is that the size of the meeting will be limited to 150 people. The conference should be "a forum for intensive discussions on basic materials science, applied physics, and device aspects of modulated semiconductor structures (MSS), representative of which are: superlattices, quantum wells, heterojunctions, and other engineered structures (including non-semiconductors)." Emphasis will be on epitaxial growth; electronic-, optical-, and other properties of MSS; and device physics. Contact, by express registered air mail, Professor J.L. Robert, Groupe d'Étude des Semiconducteurs, U.S.T.L., Place E. Bataillon, F-34060 Montpellier Cedex, France. Incidentally, the chairman of the Program Committee is Professor G. Bastard.

7. The 2nd Nordic Conference on Surface Science will be a small conference on surface physics, interfaces, and thin films; it will be held 15 through 17 June 1987 at Linköping, Sweden. Most presentations will be invited talks by international experts. Typical topics scheduled for discussion include two- and three-dimensional metal films, scanning tunneling microscopy, microanalysis of interfaces, optical studies of superlattices, MBE growth techniques, IR and IS spectroscopy, and catalysis. Contact: Ingrid Nyman, Linköping University, S-58183 Linköping, Sweden.

Paul Roman
9/26/86

ONRL COSPONSORED CONFERENCE

ONR, London, can nominate two registration-free participants in the conferences it supports. Readers who are interested in attending a conference should write to the Scientific Director, ONRL, Box 39, FPO New York 09510.

Natural Mechanisms of Surface Generated Noise in the Ocean, La Spezia, Italy, June 1987.

* * *

SCIENCE NEWSBRIEFS FOR OCTOBER AND NOVEMBER

The following issues of *Science Newsbrief* were published by the ONR, London, Scientific Liaison Division during October and November. *Science Newsbrief* provides concise accounts of scientific research developments, meeting announcements, and science policy in Europe and the Middle East. Please request copies, by number, from ONR, London.

Science Newsbrief Number	Title
4-12	Second International Conference on Polymers in a Marine Environment Announced, by David L. Venezky.
4-13	Seminars on Fluid Mechanics at the University of Cambridge, England, by Eugene F. Brown.
4-14	Call for Papers for International Conference on Bioreactors and Biotransformation, by Claire E. Zomzely-Neurath.
4-15	Pioneering Results in Image Processing at British Aerospace, by Paul Roman.

ONRL REPORTS

To request reports, indicate the report number on the self-addressed mailer and return it to ONR, London.

C-7-86 *2nd International Workshop on Neuroimmunomodulation*, by Claire E. Zomzely-Neurath. The presentations at this workshop emphasized the close interelationships of the nervous and immune systems. There were 10 sessions: neuroendocrine correlates of neuroimmodulation; enkephalins-endorphins; immunomodulators; neuroendocrine receptors in the immune system; neurophysiological correlates of neuroimmodulation; stress and immunity; behavior; associative learning and immunity; cancers, AIDS, and immunity; and psychiatric and neurological disorders with immunological features.

C-8-86 *Neurology: Sixth Meeting of the European Society for Neurochemistry*, by Claire E. Zomzely-Neurath. Topics at this meeting included biological approaches to studies of the nervous system, neuropeptides and neurotransmitters and their receptors, membrane lipids and proteins, neurotoxins, immunological approaches, neurogenesis, and neuropathology. This report focuses on topics which deal with research areas of fundamental importance for neurobiologists and are being actively pursued by European neuroscientists.

C-9-86 *Millimeter Waves, Far Infrared Radiation, and Laser Acceleration of Particles: An International Conference in Italy*, by Paul Roman. The 11th International Conference on Infrared and Millimeter Waves was held in Pisa (Tirrenia), Italy, 19 through 24 October 1986. This report covers general aspects and major features, and goes into some details in the following areas: gyrotrons, detectors, unusual radiation sources, waveguides, and particle acceleration by laser radiation (including inverse free electron lasers).

R-6-86 *Survey of Military Aerospace Systems Technology Development in Western Europe and the Middle East*, by CAPT L. Laddie Coburn, USN. Military aerospace system developments and defense aerospace R&D and manufacturing are discussed in this report. The military aerospace systems include fighter aircraft, large aircraft, helicopters, air weapons, and space systems.

R-7-86 *Gallium Arsenide Integrated Circuits and Technology*, by LCDR M. Louis Pengue, USN-R. Key efforts in gallium arsenide integrated circuits and technology in the UK and France are reviewed. The review is based on visits to five organizations working in the field, and covers the developments they are pursuing and the potential they exhibit for turning the products of their research into practical processes on manufactured components.

AUGUST SEPTEMPER OCTOBER MAS BULLETINS

The following *Military Applications Summary (MAS) Bulletins* were published by the ONR, London, Military Applications Division during August, September, and October. The *MAS Bulletin* is an account of accomplishments in European naval research, development, test, and evaluation. Its distribution is limited to offices with the US Department of Defense. DoD organizations should request copies of the *Bulletins*, by number, from ONR, London.

MASB Number	Title
42-86	German SAR Processing Hardware
44-86	British National Space Centre, Plans and Update
46-86	Farnborough Air Show Highlights--The New Canard Generation
47-86	Farnborough Air Show Highlights--Weapons
48-86	Sänger--German Two-Stage Ramjet-Rocket Spaceplane
49-86	Space Highlights 1986 Farnborough Air Show
50-86	French Spaceplane--Hermes Update
51-86	A Compact High Performance Hand-Held Thermal Imager
52-86	Gallium Arsenide (GaAs) Technology in France and England
53-86	European Wave Model Tested
54-86	Third Quarterly Index 1986
55-86	Farnborough Air Show Highlights--Avionics and Electronic Warfare

OVERSEAS TRAVELERS

Notes on trip reports to locations in Europe and the Middle East which have been received by ONRL are reported below. For details, contact the traveler directly.

Astronomy

Traveler: Dr. Donald A. Gurnett, Department of Physics and Astronomy, University of Iowa, Iowa City, Iowa 52242.

Dr. Gurnett attended the June 1986 meeting of the Solar Terrestrial Physics Advisory Group at the European Space Research and Technology Center held in Noordwijk, The Netherlands. He then attended the AMPTE Joint Science Working Group meeting at the Max Planck Institut für Extraterrestrische Physik in Garching, West Germany. In July he participated in the meeting of the 26th Committee on Space Research (COSPAR).

Physics--Semiconductors

Travellers: Drs. Gary D. De Leo, and W. Beall Fowler, both of the Department of Physics and Sherman Fairchild Center, Lehigh University, Bethlehem, Pennsylvania 18015.

Drs. LeLeo and Fowler participated in the Fourteenth International Conference on Defects in Semiconductors (ICDS-14) held in Paris, France in August 1986.

Dr. DeLeo devoted his report remarks to the presentations of two ENDOR studies on defects in silicon, a presentation on infrared studies of isotropically enriched samples of oxygen-containing silicon, and an ENDOR study on the thermal doner (NL8) in silicon.

Dr. Fowler's report emphasized questions which have not yet been settled. They concern hydrogen in silicon, the dangling bond in silicon (positive or negative U), and the thermal donor in silicon.

Traveler: Dr. Kenneth C. Hass, c/o Professor H. Ehrenreich, Department of Physics, Harvard University, Cambridge, Massachusetts 02138.

Dr. Haas participated in the 18th International Conference on the Physics of Semiconductors held in Stockholm, Sweden, in August 1986. He held extensive discussions with key scientists from Poland, West Germany, and Japan and learned considerable information on recent scientific advances, particularly in bond effects, ab initio band structure theory, and diluted magnetic semiconductors.

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